Idaho Standards Achievement Test (ISAT) in Science

2022–2023

Volume 2: Test Development

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1. INTRODUCTION

Idaho adopted the Next Generation Science Standards (NGSS) in 2018. The Idaho State Department of Education (SDE) and its assessment vendor, Cambium Assessment, Inc. (CAI; formerly the American Institutes for Research [AIR]), developed and administered a new online assessment to measure the new standards. The Idaho Standards Achievement Test (ISAT) in Science was field tested in 2020–2021 and administered operationally for the first time in 2021–2022. The ISAT in Science measures Idaho students' science knowledge and skills in grades 5, 8, and 11 as an adaptive online assessment that features several technology-enhanced item types. The content measures the three-dimensional science standards based on the National Research Council's *A Framework for K–12 Science Education* published in 2012.

Additional details on the implementation of the assessments can be found in Volume 1, Annual Technical Report.

The interpretation, usage, and validity of test scores rely heavily upon the process of developing the test itself. This volume provides details on the test development process for the ISAT in Science that contributes to the validity of the test scores. Specifically, this volume provides evidence to support the following:

- The item specifications provided detailed guidance for item writers and reviewers to ensure that science items were aligned to the performance standards they were intended to measure.
- The item development procedures employed for the ISAT in Science were consistent with industry standards.
- The development and maintenance of the Shared Science Assessment Item Bank, in which test items cover the range of measured standards, grade-level difficulties, and levels of cognitive engagement by using both item clusters and stand-alone items.
- The Test Design Summary/Blueprint stipulated the range of operational items from each item type and content category required for each test administration. The blueprint was implemented using the item selection algorithm for science.

Note that for the science assessments, as outlined in Volume 1, Annual Technical Report, CAI works with a group of states that share common item development processes. In addition to developing items for each of those states, CAI develops and maintains the Independent College and Career Readiness (ICCR) item bank, which consists of items developed according to the same principles that are followed for developing the items owned by each of the states or territory. This volume of the annual technical report focuses on the general test development activities.

For the ISAT in Science, items are drawn from the Shared Science Assessment Item Bank that consists of ICCR items, items owned by Idaho, and items owned by several other states that share a Memorandum of Understanding (MOU) to share content, leadership, and new ideas and methods. Specifically, all items developed under the MOU underwent the same development process. For the remainder of this volume, the term *item bank* will refer to all items developed under the MOU unless stated otherwise.

1.1 Claim Structure

The goals, uses, and claims that the Shared Science Assessment Item Bank and subsequent tests were designed to support were identified in a series of collaborative meetings held over August 22–23, 2016. The overarching goal of these meetings was to support the development of statewide summative assessments using science content that measures the three-dimensional science standards based on *A Framework for K–12 Science Education* (National Research Council, 2012).

To this end, CAI invited content and assessment leaders (e.g., Directors of Assessments) from ten states and four nationally recognized experts, Aneesha Badrinarayan, Rodger Bybee, Peter McLaren, and Brett Moulding, who helped author the NGSS. Two nationally recognized psychometricians, Laurie Wise, Ph.D. and Tom Hirsch, PhD., also participated.

CAI staff and participating states collaborated to develop items and test specifications that would measure the three-dimensional science standards. The item specifications were generally accompanied by sample item clusters that met those specifications. At the time, some standards did not have sample item clusters available. All specifications and sample item clusters were reviewed by state content experts and committees of educators in at least one of the states.

1.2 Underlying Principles Guiding Development

The Shared Science Assessment Item Bank was established using a highly structured, evidence-centered design. The process began with detailed item specifications. The specifications, discussed in Section 2.2, Item Specifications, described the interaction types that could be used, gave guidelines for targeting the appropriate cognitive engagement, offered suggestions for controlling item difficulty, and provided sample items.

Items were written with the goal that virtually every item would be accessible to all students, either by itself or in conjunction with accessibility tools, such as text-to-speech (TTS), translations, or assistive technologies. This goal is supported by the delivery of the items on CAI's Test Delivery System (TDS), which has received Web Content Accessibility Guidelines (WCAG) 2.0 AA certification, offers a wide array of accessibility tools, and is compatible with most assistive technologies.

Item development supported the goal of high-quality item clusters and stand-alone items through rigorous development processes managed and tracked by a content development platform. This platform ensures that every item flows through the correct sequence of reviews and captures every comment and change to the item.

CAI sought to ensure that the items measured the performance standards in a fair and meaningful way by engaging educators, state officials, content experts, and fairness, bias, and sensitivity experts at each step of the process. Educators evaluated the alignment of the items to the standards and offered guidance and suggestions for improvement. These educators participated in the review of items for fairness and sensitivity. Following item field-testing, educators engaged in rubric validation, a process that refines rule-based rubrics upon review of student responses.

Combined, these principles and the processes that support them have been incorporated into an item bank that measures the standards with fidelity and does so in a way that minimizes construct-irrelevant variance and barriers to access. The details of these processes are described in this volume of the annual technical report.

1.3 ORGANIZATION OF THIS VOLUME

This volume is organized into the following three sections:

1. An overview of the science item development process that supports the validity of the claims that science tests are designed to support.
2. An overview of the science item bank[1], the types of assessments the item bank is designed to support, and methods for refreshing the item bank.
3. A description of the test construction process for the ISAT in Science, including the blueprint, the test design, an evaluation of simulated test sessions, the operational blueprint match results, and the item exposure rates.

2. ITEM DEVELOPMENT PROCESS THAT SUPPORTS VALIDITY OF CLAIMS

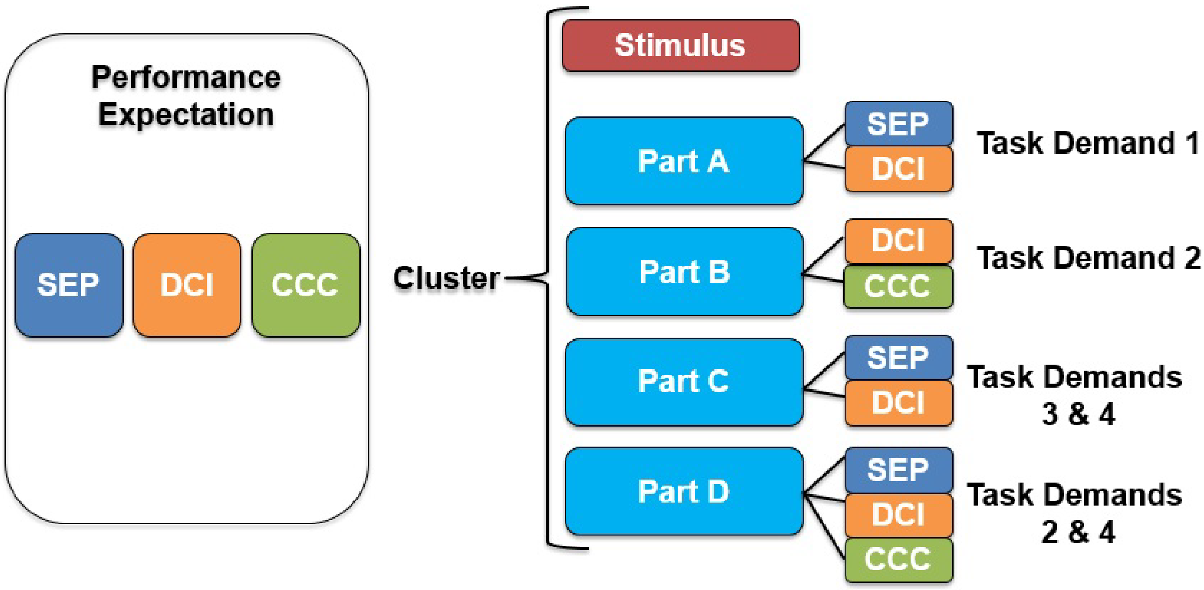
2.1 OVERVIEW

Cambium Assessment, Inc. (CAI) developed the Shared Science Assessment Item Bank in collaboration with the states that were part of the Memorandum of Understanding (MOU) using a rigorous, structured process that engaged stakeholders at critical junctures. This process was managed by CAI's Item Tracking System (ITS), which is an auditable content-development tool that enforces rigorous workflow and captures each item change and comment. Reviewers, including internal CAI reviewers or stakeholders in committee meetings, can review items in ITS as they will appear to the student, with all accessibility features and tools.

A performance expectation is a point in a three-dimensional space formed by three dimensions of science learning: crosscutting concepts (CCCs), science and engineering practices (SEPs), and disciplinary core ideas (DCIs). That is, a performance expectation (PE) is characterized by a specific CCC, SEP, and DCI. When the MOU states first convened, many sessions were spent discussing how to assess these new three-dimensional standards. These group sessions are where the idea of an item cluster was conceived. An *item cluster* consists of a stimulus (scientific phenomenon) associated with multiple parts. Each of these parts contain questions that allow the student to explore the phenomenon. Each of the parts assess at least two dimensions, and the entire item cluster assesses a student on all three dimensions for a specific PE. Figure 1 is a visual representation of the structure of a three-dimensional cluster.

[1]This is often referred to as the Shared Science Assessment Item Bank.

Figure 1. Structure of Three-Dimensional Item Clusters



Each part of an item cluster contains questions that require the student to interact with the item cluster. There are many different interactions that can be included in an item cluster. Section 3.1, Current Composition of the Shared Science Assessment Item Bank, describes and lists all of the different interactions available. The interactions used in an item cluster are chosen intentionally to best assess different aspects of the three-dimensional construct.

Figure 2 provides an example of an item cluster that has a phenomenon, five parts, and eight interactions; each part of an item cluster assesses multiple dimensions.

Figure 2. Example of an NGSS Item Cluster

A student rings a doorbell. When the person inside the house is on the main floor, he can easily hear the doorbell. When he is upstairs, though, he cannot so easily hear the doorbell.

Figure 1 shows the circuit of a simple doorbell when it is on (pressed) and off (not pressed).

Figure 1. Simple Doorbell Circuit

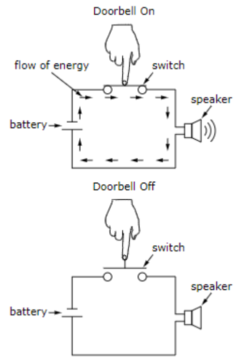


Table 1 shows the types of doorbell speakers available and their cost, in dollars ($).

Table 1. Types of Speakers and Cost

Speaker	Cost ($)
Bell	11
Buzzer	17
Chimes	25

Table 2 shows the types of batteries available based on their voltage (V), the amount of power each produces, and their cost.

Table 2. Types of Batteries and Cost

Battery (V)	Amount of Power	Cost ($)
12	A lot	27
9	Average	3
1.5	A little	1

Table 3 shows the types of switches and their cost.

Table 3. Types of Switches and Cost

Switches	Cost ($)
Rectangular	4
Circular	5
Lighted	11

Your Task

In the questions that follow, you will design a main-floor doorbell that can be heard from upstairs in a house.

Part A

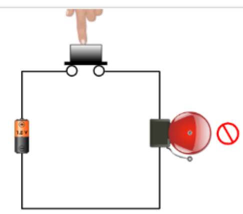
Click on each blank box and select a phrase to describe what is happening to the energy at each part of the circuit when the doorbell is turned on.

Parts	Energy Pathway when Doorbell Is on
Battery	Energy is stored.
Wires	Energy is transferred.
Speaker	Electrical energy is converted to sound energy.

Part B

Use the simulation to select the materials necessary to conduct fair experiments and create a doorbell that can be heard from upstairs and costs less than $40. The student can only hear a doorbell from upstairs if it is loud or very loud.

- Select the speaker, battery, and switch to determine the overall cost and loudness of the doorbell.
- Then click Run Trial.
- The cost of wire has already been included in the total cost.
- You must complete **two** trials.
- You may run up to **five** trials.
- Click the trash can icon if you want to delete a trial and generate new data.



Speaker: Bell
Battery: 1.5
Switch: Rectangular
Run Trial

Trial	Speaker	Battery (V)	Switch	Loudness	Cost ($)
1	Bell	9.0	Rectangular	Loud	18
2	Bell	12.0	Rectangular	Very Loud	42
3	Bell	1.5	Rectangular	No Sound	16
4	Chimes	9.0	Lighted	Quiet	39
5	Bell	9.0	Lighted	Loud	25

Part C

Select **all** of the trials that meet the criteria for being heard upstairs and cost less than $40.

- [x] Trial 1
- [ ] Trial 2
- [ ] Trial 3
- [ ] Trial 4
- [x] Trial 5
- [ ] None

Part D

Click on the blank boxes and select words or phrases to predict what will happen to the loudness of the doorbell when the battery power increases.

The loudness of the doorbell will increase because more energy is stored in the battery.

Part E

Select **two** trials that support the relationship between the loudness of the doorbell and the power of the battery.

- [ ] Trial 1
- [x] Trial 2
- [x] Trial 3
- [ ] Trial 4
- [ ] Trial 5
- [ ] Cannot be determined

This item cluster is aligned to the NGSS PE of 4-PS3-4: Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. The PE uses the following three elements of the three-dimensional standards: (1) Constructing Explanations and Designing Solutions (i.e., SEP), (2) Conservation of Energy and Energy Transfer (i.e., DCI), and (3) Energy and Matter (i.e., CCC).

Part A requires students to demonstrate their knowledge of how energy is stored, transferred, or used within the system. In this item cluster, they must know how a battery, wires, and a speaker work within the circuit. This aligns with the DCI and the CCC.

Part B requires students to design and test designs that use electricity to produce a sound. This aligns with the DCI (how changes in current influence the production of sound) and the SEP (designing and testing solutions to a design problem).

Part C requires students to compare their designs with some criteria and constraints. This aligns with the SEP (designing and testing solutions) and the CCC (energy can be transferred in various ways and between objects). The answer for Part C is directly determined by how the student completes Part B. If all of the trials the student runs in Part B meet the given criteria, then all of those must be selected to be considered as correct in Part C. Therefore, there are multiple different ways to get this item correct.

Part D requires students to make a prediction from the evidence that they generated in Part B. This part is aligned to all three dimensions. The student has used their designs and information (representing SEP) from Part B to show how energy is transferred between objects (representing CCC) and specifically how increasing the current changes the volume (representing DCI).

Like Part C, Part E is dependent on Part B. Students are determining which trials support the prediction that they made in Part D. This part, combined with Part D and Part B, addresses all three dimensions of the PE.

The next big challenge for the MOU states was to properly score these item clusters so that all evidence of understanding the PEs and three dimensions could be collected. It was determined that scoring assertions would be the best way to capture and score student responses on item clusters. Scoring assertions were evidence statements that related specific features from the student response to skills and knowledge that were tested (of which they provide evidence). The use of these assertions in scoring created a direct linkage between what the student does and the inferences about the skills and knowledge that the student's response supports. This approach provided a physical embodiment of evidence-centered design, Mislevy and Haertel's well-regarded approach to cognitive measurement (Mislevy & Haertel, 2006). This also provided a structure for ensuring and reviewing alignment during test development and a clear explanation of what was measured, how it was measured, and why it was measured when tests were scored and reported.

By inspecting the student response for every meaningful piece of student input, more information about student skills and knowledge can be harvested than in a single interaction. In fact, evidence for some scoring assertions may derive from two or more interactions within an item cluster. This may happen if one interaction is dependent on another interaction, allowing for multiple solution paths. This is one of the primary reasons that scoring assertions within item clusters can show deeper cognitive understanding and higher-order thinking that is required of the three-dimensional science standards.

Each of the parts in an item cluster likely has one or more scoring assertions where student skills and knowledge are being collected. The scoring mechanism has the capability to focus on one interaction, one part, or to focus across multiple interactions and parts as determined by the item writers, subject-matter expert (SME) reviewers and performance expectations. All permutations and combinations of measurable actions can be captured with scoring assertions.

The example item cluster from this section has seven assertions. Each scoring assertion is described in detail in Figure 3.

Figure 3. Example of NGSS Scoring Assertions

Your response earned **7** points of a possible **7**

Score Rationale	
When asked to describe what is happening to the energy for the battery when the doorbell is turned on, the student selected "energy is stored" or "energy is transferred." This provides some evidence of an ability to complete a causal chain explaining how energy can be transferred via electric current to produce light, sound, heat, and /or motion.	✓
When asked to describe what is happening to the energy of the wires when the doorbell is turned on, the student selected "energy is transferred." This provides some evidence of an ability to complete a causal chain explaining how energy can be transferred via electric current to produce light, sound, heat, and /or motion.	✓
When asked to describe what is happening to the energy of the speaker when the doorbell is turned on, the student selected "electrical energy is converted to sound energy." This provides some evidence of an ability to complete a causal chain explaining how energy can be transferred via electric current to produce light, sound, heat, and /or motion.	✓
The student ran at least two trials and ran at least one trial in which they selected components of a doorbell that produced "Loud" or "Very Loud" sound and that included components that cost less than $40. This provides some evidence of an ability to select characteristics to be manipulated while gathering information to determine the loudest, cost-effective doorbell.	✓
When asked to select the trial that met the criteria for being heard upstairs and cost less than $40, the student selected all trials from their simulation that produced "Loud" or "Very Loud" sound and cost less than $40. This provides some evidence of an ability to use given information to design and test a device that converts energy from one form to another.	✓
When asked to predict what will happen to the sound of the doorbell if the battery power increases, the student selected "The loudness of the doorbell will increase because more energy is stored in the battery." This provides some evidence of an ability to use an explanation to predict how the sound of an object changes, given a change in the conversion of stored energy.	✓
When asked to select the trials that support the relationship between the loudness of the doorbell and the power of the battery, the student selected two trials from the simulation in which the loudness was higher for the trial with a battery with more power. This provides some evidence of an ability to use evidence to support an inference.	✓

Assertion texts like the one shown in Figure 3 are written for every assertion in every item. They describe the correct response and what evidence should be provided by the student's response.

In the example item cluster, Part A has three assertions. Each one "provides some evidence of an ability to complete a causal chain explaining how energy can be transferred via electric current to produce light, sound, heat, and/or motion." The student must know something about electrical energy (DCI) and how it is transferred or used (DCI and CCC) to correctly respond. One assertion corresponds to each row in the table (i.e., one for Battery, one for Wires, and one for Speaker).

Part B has two assertions. The first "provides some evidence of an ability to select characteristics to be manipulated while gathering information to determine the loudest, most cost-effective doorbell." The second assertion "provides some evidence of an ability to use given information to design and test a device that converts energy from one form to another." The student must use their knowledge of how electrical energy is used and transferred (DCI) and how to design and test a design of a device using electricity (SEP) to correctly interact with Part B.

Part C has one assertion, as the student's selections are not independent of each other. The assertion "provides some evidence of an ability to use given information to design and test a device that converts energy from one form to another." The student must be able use generated evidence to support a design decision (SEP) about the transfer of energy (CCC). This assertion is pulling responses from both Parts B and C. This is precisely how item clusters and assertions can assess multiple dimensions and higher levels of complexity, as students are running their own experiments and analyzing the outcomes, no matter what those outcomes are.

Part D has one assertion. The assertion "provides some evidence of an ability to use an explanation to predict how the sounds of an object changes, given a change in the conversion of stored energy." This shows how the student must use elements from all three dimensions to respond correctly to this assertion. The student uses data from their generated designs and makes a prediction using that data to support their knowledge of energy and energy transformations.

Part E also has one assertion. The assertion "provides some evidence of an ability to use evidence to support an inference." In this case, it is an inference about the relationship between the available battery power and the loudness of the bell. Again, this scoring assertion is pulling information from three different parts (Parts B, D, and E).

While each part of the item, each interaction within the item, or each assertion may not be three-dimensional, the item cluster as a whole represents all three dimensions. It also provides an organized flow of cognition from scaffolding (Part A), through the engineering process (Parts B and C), to a conclusion and evidentiary support of the conclusion (Parts D and E).

The assertion text explains how a student responded to a given task and what that task shows evidence of. This allows us to ensure that items allow each student an opportunity to show what they know and what their knowledge, skills, and abilities show about their understanding of science and engineering.

Once the item cluster, along with interactions and scoring assertions, came to fruition, CAI and the group of states were able to begin item and test development in earnest.

The item development process was managed by CAI's Item Tracking System (ITS), which is an auditable content-development tool that enforces rigorous workflow and captures each item change and comment. Reviewers, including internal CAI reviewers or stakeholders in committee meetings, can review items in ITS as they will appear to the student, with all accessibility features and tools.

The process begins with the definition of item specifications, and continues with

- selection and training of item writers;
- writing and internal review of items;

- review by state personnel and stakeholder committees;
- markup for translation and accessibility features;
- field-testing; and
- post-field-test reviews.

Each step has a role in ensuring that the items can support the claims on which they will be based. Table 1 describes how each step contributes to these goals and describes each step in the process in more detail.

Table 1. Summary of How Each Step of Development Supports the Validity of Claims

Developmental Steps	Support Alignment to the Performance Standards	Reduce Construct-Irrelevant Variance Through Universal Design	Expand Access Through Linguistic and Other Supports
Item specifications	Specifies item interactions, content limits, and guidelines for meeting task demands and levels of cognitive engagement requirements and adjusting difficulty.	Avoids the use of any item interactions with accessibility constraints and provides language guidelines. Allows for multiple response modes to accommodate different styles.	
Selection and training of item writers	Ensures that item writers have the background to understand the performance standards and item specifications. Teaches item writers how to select item interactions for measurement and accessibility.	Training in language accessibility, and bias, and sensitivity helps item writers avoid unnecessary barriers.	
Writing and internal review of items	Checks content alignment and evaluates and improves overall quality.	Eliminates editorial issues and flags and removes bias and accessibility issues.	
Markup that prepares items for translation and accessibility features		Adds universal features, such as text-to-speech (TTS) for science, that reduce barriers.	Adds TTS, braille, American Sign Language (ASL), translations, and glossaries.
Review by state personnel and stakeholder committees	Checks content and cognitive complexity alignment; evaluates and improves overall quality.	Flags sensitivity issues.	
Field-testing	Provides statistical checks on quality and flags issues.	Flags items that appear to function differently for subsequent review to identify issues.	May reveal usability or implementation issues with markup.

Developmental Steps	Support Alignment to the Performance Standards	Reduce Construct-Irrelevant Variance Through Universal Design	Expand Access Through Linguistic and Other Supports
Post-field-test reviews	Provides final, more focused checks on flagged items. Rubric validation ensures that scoring reflects standards.	Provides final, focused review on items flagged for differential item functioning (DIF).	

2.2 ITEM SPECIFICATIONS

CAI is working with a group of states and one U.S. territory, psychometricians, and science experts, including the authors of the NGSS, to develop powerful innovative solutions to the challenges of measuring three-dimensional science standards based on the National Research Council's *A Framework for K–12 Science Education* published in 2012. Participating states, included Connecticut, Hawaii, Idaho, Montana, Oregon, Rhode Island, Utah, West Virginia, and Wyoming were involved in all activities. New Hampshire, North Dakota, South Dakota, and U.S. Virgin Islands participated in some activities. This collaboration has yielded item specifications for performance expectations (PEs)[2], sample item clusters for some specifications, and hundreds of science item clusters and stand-alone items in various stages of development. Under this collaboration, these states and the U.S. Virgin Islands jointly developed item specifications using the guidelines proposed by WestEd in conjunction with the Council of Chief State School Officers (CCSSO), state and territory members, and content experts (CCSSO, 2015).

Item specifications are documents designed to guide item writers as they craft test questions and stakeholders as they review those items. These specifications are intended to serve as a roadmap for writers to facilitate the creation of items that are properly aligned to the three dimensions comprising each science standard and that together form coherent item clusters and stand-alone items. Table 2 provides a sample of the item specifications developed by content experts for a middle school Life Sciences PE. Item specifications in Science include the following:

- **Performance Expectations/Performance Standards.** The PE provides the unique identifier and the text for the PE.
- **Dimensions.** The dimensions identify the CCCs, SEPs, and DCIs that the standard assesses.
- **Clarifications and Content Limits.** This section delineates the specific content that the PE measures and the parameters in which items must be developed to assess the PE accurately, including the lower and upper complexity limits of items. Specifically, content limits refine the intent of the PE and provide limits of what may be asked of

[2]Performance expectations under the NGSS framework are similar to performance standards in the Idaho State Science Standards.

test takers. For example, content limits may identify the specific formulae that students are expected to know or not know.

- **Science Vocabulary.** The science vocabulary outlines the relevant technical words that students are expected to know, and related words that they are explicitly not expected to know. These categories should not be considered exhaustive, as the boundaries of relevance are ambiguous, and the list is limited by the imagination of the writers.
- **Content/Phenomena.** Examples of the types of content/phenomena that support creating effective items related to the standard in question. In general, these are guideposts, and item writers seek comparable phenomena, rather than drawing on those within the documents.
- **Task Demands.** The task demands denote the specific ways students will be expected to provide evidence of their understanding of the concept or skill. Specifically, the task demands identify the types of interactions and activities that item writers should employ. The standards and associated evidence statements are broken down into specific task demands aligned to each standard. Item writers are required to clearly link each item to one or more task demand, and the verbs guide the types of interactions writers might employ to elicit the student response.

Table 2 provides a sample of the item specifications developed by content experts for a middle school Life Sciences performance standard.

Table 2. Sample Science Item Cluster Specifications for Middle School Life Sciences Performance Expectation

Performance Expectation	**LS1-MS-1**[a] Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.		
Dimensions	**Planning and Carrying Out Investigations** • Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation.	**LS1.A: Structure and Function** • All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).	**Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is placed on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many varying cells. **Content Limits** • Students do not need to know the following: o The structures or functions of specific organelles or different proteins o Systems of specialized cells		

	○ The mechanisms by which cells are alive ○ Specifics of DNA and proteins or of cell growth and division ○ Endosymbiotic theory ○ Histological procedures
Science Vocabulary Students Are Expected to Know	Multicellular, unicellular, cell, tissue, organ, system, organism hierarchy, bacteria, colony, yeast, prokaryote, eukaryote, magnify, microscope, DNA, nucleus, cell wall, cell membrane, algae, chloroplast(s), chromosome, cork
Science Vocabulary Students Are Not Expected to Know	Differentiation, mitosis, meiosis, genetics, cellular respiration, energy transfer, RNA, protozoa, amoeba, histology, protists, archaea, nucleoid, plasmid, diatoms, cyanobacteria
Phenomena	
Context/ Phenomena	Some example phenomena for LS1-MS-1 include the following: • Plant leaves and roots have tiny, box-like structures that can be seen under a microscope. • Small creatures can be seen swimming in samples of pond water viewed through a microscope. • Different parts of a frog's body (e.g., muscles, skin, tongue) are observed under a microscope, and are seen to be composed of cells. • One-celled organisms (e.g., bacteria, protists) perform the eight necessary functions of life, but nothing smaller has been seen to do this. • Swabs from the human cheek are observed under a microscope. Small cells can be seen.
This Performance Expectation and Associated Evidence Statements Support the Following Task Demands	
Task Demands	
1. Identify from a list the materials/tools, including distractors, needed for an investigation to find the smallest unit of life (cell).	
2. Identify the outcome data that should be collected in an investigation of the smallest unit of living things.	
3. Evaluate the sufficiency and limitations of data collected to explain that the smallest unit of living things is the cell.	
4. Make and/or record observations about whether the sample contains cells.[b]	
5. Interpret and/or communicate data from the investigation to determine if a specimen is alive.	
6. Construct a statement to describe the overall trend suggested by the observed data.	

[a]LS1-MS-1 is the PE code for Middle School Life Sciences 1-1.
[b]Denotes task demands deemed appropriate for use in stand-alone item development.

The specifications help test developers create item clusters and stand-alone items that will support a range of difficulty, furthering the goal of measuring the full range of performance found in the population, but remaining at grade level.

2.3 Selection and Training of Item Writers

All item writers developing science items at CAI have at least a bachelor's degree, and many bring teaching experience. All item writers are trained in

- the principles of universal design;
- the appropriate use of item interactions; and
- the science item specifications.

Key materials are shown in *Appendix 2-A, Item Writer Training Materials*, *Appendix 2-B, Item Specifications Grade 3 through High School*, and *Appendix 2-C, Style Guide for Science Items*. These include

- CAI's language accessibility, bias, and sensitivity (LABS) guidelines;
- a training (presented using Microsoft PowerPoint) for the appropriate use of item interactions;
- item specification for science for grades 3 through high school; and
- style guide for science items.

2.4 Internal Review

CAI's test development structure uses highly effective units organized around each content area. Unit directors oversee team leaders who work with team members to ensure item quality and adherence to best practices. All team members, including item writers, are content-area experts. Teams include senior content specialists who review items before client review and provide training and feedback for all content-area team members.

ICCR and MOU science items undergo a rigorous, multi-level internal review process before they are sent to external review. Staff members are trained to review items for both content and accessibility throughout the process. A sample item review checklist that our test developers use is included in *Appendix 2-D, Item Review Checklist*. The ICCR and MOU science internal review cycle includes the following phases:

- Preliminary Review
- Scoring Entry and Review
- Content Review One
- Edit Review
- Senior Review

2.4.1 Preliminary Review

Team leads or senior content staff conduct Preliminary Review. Sometimes, Preliminary Review is conducted in a group setting, led by a senior test developer. During the Preliminary Review process, team leads or senior content staff analyze items to ensure the following:

- The item aligns with the PE, including the listed SEP, DCI, and CCC. The item matches the item specification for the skills and knowledge being assessed. The item specification contains clarifying statements, content limits, and task demands, as well as knowledge, skills, and abilities that the PE is intended to assess.
- The item is based on a quality scientific phenomenon (i.e., it assesses something in a reasonable way, and it is a discrete observation that grounds a scenario, which allows for the assessment of something worthwhile in a meaningful way). A quality phenomenon is one that is natural, observable (even with instrumentation), and focused on a specific event, not a general category of similar events (e.g., the effects of Hurricane Katrina, not hurricanes in general).
- The item aligns appropriately with the task demands. Task demands are statements about what a student is expected to do with a phenomenon.
- The vocabulary used in the item is appropriate for the grade and subject matter. Most non-technical language is two grade levels below the testing grade to ensure that language is not a construct-irrelevant issue.
- The item considers language accessibility, bias, and sensitivity.
- The content is accurate and straightforward.
- The graphic and stimulus materials are necessary to answer the question. The phenomenon is described in the stimulus. Graphics are necessary and contain only the relevant information.
- The item follows the approved style guide.
- The stimulus is clear, concise, and succinct (i.e., it contains enough information to convey what is being asked, it is stated positively, and it does not rely on negatives—such as *no, not, none,* or *never*—unless necessary).

For selected-response item interactions, test developers also check to ensure that the set of response options are

- as succinct and short as possible (e.g., without repeating text);
- parallel in structure, grammar, length, and content;
- sufficiently distinct from one another;
- all plausible (but with only one correct option); and
- free of obvious or subtle cuing.

2.4.2 Scoring Entry and Review

During Scoring Entry, the item writer inputs the machine scoring for review by the team lead or senior staff before the Content Review One level. This step is separate from Preliminary Review to allow senior staff to suggest changes to the interaction at Preliminary Review without requiring the writer to overhaul the scoring they already created, ensuring that the scoring is entered once, streamlining the process. This step also allows senior staff to ensure that the scoring suggested by the writer at Preliminary Review is appropriate. At this level, scoring is analyzed to ensure the following criteria:

- The scoring works as intended (i.e., the student gets a point for ALL correct responses and no points for ALL incorrect responses).
- The student receives a point for every unique piece of information they reveal about their understanding through their responses.
- Dependent scoring between and within interactions is captured.
- The way in which the scoring is set up is unambiguous and matches the questions asked (i.e., if we ask students to round a number to a certain decimal place, we score accordingly).

The senior staff approves the intent of the scoring from the Preliminary Review. At the Scoring Entry level, the writer inputs the approved scoring, after which senior staff checks the functionality of the scoring. Once the scoring is determined to be working correctly, the senior staff signs off on the item and moves it to Content Review One.

Senior staff are recruited based on experience and time in the assessment field. Senior staff are the reviewers of the intent of scoring because of their experience and knowledge of assessment, the expectations of the clients, and their understanding of student responses.

2.4.3 Content Review One

Content Review One is conducted by a senior content specialist who was not part of the Preliminary Review. This reviewer carefully examines each item based on the same criteria identified for Preliminary Review. They also ensure that the revisions made during the Preliminary Review did not introduce errors or content inaccuracies. This reviewer approaches the item by combining their expertise in test development while engaging from the perspective of potential clients and their expertise in test development.

2.4.4 Edit Review

During Edit Review, editors have four primary tasks:

1. Editors perform basic line editing for correct spelling, punctuation, grammar, and mathematical and scientific notation, ensuring consistency of style across the items.
2. Editors ensure that all items are accurate in content. Editors compare reading passages against the original publications to ensure that all information is internally consistent across stimulus materials and items, including names, facts, or cited lines of text that

appear in the item. They ensure that the keys and all information in the item are correct. Keys are the correct answers to interactions. Information refers to the phenomena and the science content. For items with mathematical tasks, editors perform all calculations to ensure accuracy.

3. Editors review all material for fairness and language accessibility issues.

4. Editors confirm that items reflect the accepted guidelines for good item construction. They examine all items for language that is simple, direct, and free of ambiguity with minimal verbal difficulty. Editors confirm that a problem or task and its stem are clearly defined and concisely worded with no unnecessary information. For multiple-choice interactions, editors check that options are parallel in structure and fit logically and grammatically with the stem. They also ensure that the key answer (i.e., correct answer) answers the question posed accurately and correctly, is not inappropriately obvious, and is the only correct answer to an item among the distractors. For constructed-response interactions, editors review the rubrics for appropriate style and grammar.

2.4.5 Senior Review

By the time a science item arrives at Senior Review, both content reviewers and editors have thoroughly vetted it. Senior reviewers (in particular, senior content specialists) look at the item's entire review history, ensuring that all the issues identified in that item have been adequately addressed. Senior reviewers verify the overall content of each item, confirming its accuracy, alignment to the PE, and consistency with expectations for the highest quality. They check whether the scoring is working as intended and scoring assertions adequately address the evidence the student provides with each type of response.

Some examples of questions from the internal Review Checklist are listed below. These are the questions that reviewers ask of the item to ensure that it is three dimensional and properly aligned to the PE. A similar checklist is used at earlier stages.

- Is the phenomenon based on a specific real-world scenario and focused enough to get the student to investigate what the PE intends for them to investigate (i.e., the students' application of the Practice in the context of the DCI and CCC as intended by the PE is sufficient to make sense of the phenomena)?
- What information should the student already have before starting the cluster (DCI knowledge)?
- Cluster Task Statement: Does it align to the focus and intent of the PE?
- Does the interaction require the student to demonstrate the science practice and/or content that the PE is assessing them on?
- Do the interactions align with the task demands?

2.5 REVIEW BY STATE PERSONNEL AND STAKEHOLDER COMMITTEES

All science items undergo an exhaustive external review process. Items in the Shared Science Assessment Item Bank were reviewed by content experts in one or several states and reviewed and approved by multiple stakeholder committees that evaluated them for both content and bias and sensitivity.

2.5.1 State Review

After items have been developed for a state participating in the MOU, content experts from the state that owns the item review any eligible items before committee review. At this stage in the review process, clients can request edits, such as wording edits, scoring edits, alignment changes, or task demand updates. A CAI science content expert reviews all client-requested edits considering the science item specifications, other clients' requests, and existing items in the bank to determine whether the requested edits will be made. At this stage, clients have the option to present these items to the committee (based on the edits made) or withhold them from committee review.

ICCR items are reviewed by at least three individuals from one or more states in the MOU. The states or territory provide feedback on the ICCR items, and CAI science leadership gathers suggestions and makes edits that improve the ICCR item. Not all suggestions are implemented, as CAI owns these items. Further, most MOU states or territory accept or reject ICCR and MOU items (as they appear at the time) to be presented to their committees. Some clients skip this step and allow CAI to review all items with their committees before reviewing them. These items can be either set for field-testing in a future administration or become a part of the locked operational pool.

2.5.2 Content Advisory Committee Reviews

During the Content Advisory Committee (CAC) reviews, items are reviewed for content accuracy, grade-level appropriateness, and alignment to the PE. CAC members are typically grade-level and subject-matter experts. During this review, educators also ensure that the scoring assertions clearly identify what is being scored as correct and give credit where they should (refer to Section 2.7.1, Rubric Validation). Before the CAC review begins, CAI provides a presentation on the three-dimensional science standards, the item development process, the CAI systems that will be used in the review, and how to review the items for content.

Items developed for each state under the MOU are reviewed by the state that owns those items. ICCR items are reviewed by the CAC of one or more states. In most cases, items are seen by multiple state committees before their field-test or operational use.

In 2023, the MOU states were all involved in a single CAC process where participants from multiple states reviewed items. The items were edited and then returned to the owning state for final approval.

A summary of 2022-2023 the committee meetings is presented in Table 3, with additional details about the participants in *Appendix 2-E, Content Advisory Committee Participant Details*. Appendix E also contains detailed information about the participants of CAC meetings of previous years.

Table 3. Summary of the 2022-2023 Content Advisory Committee Meetings

State/ Item Bank	Meeting	Number of Committee Members	Number of Items Reviewed
Connecticut	June/ August 2022[a]	26	65
	July 2022	21	62
Hawaii	June/ August 2022[a]	25	46
	July 2022	9	45
	July 2022	9	306
ICCR	June/ August 2022[a]	12	121
Idaho	June/ August 2022[a]	14	12
	July 2022	5	244
Montana	June/ August 2022[a]	9	13
Oregon	July 2022	14	66
Rhode Island	October 2022	20	115
Utah	September 2022	28	111
West Virginia	June/ August 2022[a]	8	13
Wyoming	June/ August 2022[a]	9	37

[a]Items were reviewed in a combined Content Advisory Committee Meeting that included ICCR and MOU state-owned items. Items reviewed in the combined meetings are displayed by their respective state or bank of ownership.

2.5.3 Language Accessibility, Bias, and Sensitivity Committee Reviews

During bias and sensitivity reviews, stakeholders review items to check for issues that might unfairly impact students based on the students' background. For example, some states or territories include representatives from student populations such as special education, low vision, and the hearing impaired. Further, diverse members of this committee represent students of various ethnic and economic backgrounds to ensure that all items are free of bias and sensitivity concerns. States try to ensure that all demographics are represented when providing committee members. For example, if a state has a Native American population, they will try to ensure that the Bias and Sensitivity Committee has Native American representation on the committee. Before the bias and sensitivity review begins, CAI provides a presentation on the three-dimensional science standards, the item development process, the CAI systems that will be used in the review, and how to review the items for fairness.

During 2020–2022, due to the COVID-19 pandemic, CAI reviewed items that contained references to virus, vaccine, bacteria, disease, infection, and related words and phrases. CAI content experts reviewed 65 items and rejected one item for sensitivity concerns.

In 2023, the MOU states were all involved in a single review process where participants from multiple states would review items. The items were edited and then returned to the owning state for final approval.

A summary of the 2022-2023 committee meetings is presented in Table 4, with additional details about the participants in *Appendix 2-F, Fairness Committee Participant Details*. Appendix 2-F also contains detailed information about the participants of Fairness Committee meetings of previous years.

Table 4. Summary of the 2022-2023 Fairness Committee Meetings

State/ Item Bank	Meeting	Number of Committee Members	Number of Items Reviewed	Number of Items Rejected
Connecticut	June/ August 2022[a]	3	65	2
	August 2022	19	154	27
Hawaii	June/ August 2022[a]	6	46	0
	July 2022	9	45	0
	July 2022	9	306	0
ICCR	June/ August 2022[a]	7	121	3
Idaho	June/ August 2022[a]	4	12	0
Montana	June/ August 2022[a]	4	13	0
Oregon	July 2022	9	43	2
Rhode Island	October 2022	20	115	22
Utah	September 2022	28	111	12
West Virginia	June/ August 2022[a]	3	13	0
Wyoming	June/ August 2022[a]	6	37	0

[a]Items were reviewed in a combined Fairness Committee Meeting that included ICCR and MOU state-owned items. Items reviewed in the combined meetings are displayed by their respective state or bank of ownership.

2.5.4 Markup for Translation and Accessibility Features

After all approved state/territory- and committee-recommended edits have been applied, the items are considered "locked" and ready for a portion of the accessibility tagging. Text-to-speech (TTS) tagging is applied prior to field testing while Spanish translations and braille are applied post-field-testing. Accessibility markup is embedded into each item as part of the item development process rather than as a *post-hoc* process applied to completed tests.

Accessibility markup, whether for translations or TTS, follows similar processes. One trained expert enters the markup, and then a second expert reviews the work and recommends changes if necessary. If there is disagreement, a third expert is engaged to resolve the issue.

Currently, science items are tagged with TTS. Spanish translations, including Spanish TTS and braille, are available for a subset of items.

2.6 Field Testing

A large pool of science field-test items was administered in the following nine states in spring 2018: Connecticut, Hawaii, New Hampshire, Oregon, Rhode Island, Utah, Vermont, West Virginia, and Wyoming[3]. For Hawaii, Oregon, and Wyoming, items were embedded as field-test

[3]Idaho joined in 2019 after the Idaho SDE adopted the new Idaho State Science Standards in 2018.

items in the legacy science test. Connecticut and Rhode Island conducted an independent field test in which all students participated, but no scores were reported. In New Hampshire, Utah, Vermont, and West Virginia, an operational field test was administered.

In 2019, a second pool of field-test items was administered in the following nine states: Connecticut, Hawaii, Idaho, New Hampshire, Oregon, Rhode Island, Vermont, West Virginia, and Wyoming. For Hawaii, Idaho (elementary school), and Wyoming, unscored field-test items were added as a separate segment to the operational (scored) legacy science test. An independent field test in which students were administered a full set of items was conducted for a sample of Idaho middle schools. In Connecticut, New Hampshire, Oregon, Rhode Island, Vermont, and West Virginia, field-test items were administered as unscored items embedded within the operational items.

In 2021, a third wave of field-test items was administered in 12 states: Connecticut, Hawaii, Idaho, Montana, New Hampshire, North Dakota, Rhode Island, South Dakota, Utah, Vermont, West Virginia, and Wyoming. An independent field test, in which students were administered a full set of items, was conducted for Idaho and Montana. Unscored field-test items were added as a separate segment to the operational (scored) legacy science test for Wyoming. In the remaining nine states, field-test items were administered as unscored items embedded within the operational items.

In 2022, a fourth wave of field-test items was administered in 13 states and one U.S. territory: Connecticut, Hawaii, Idaho, Montana, New Hampshire, North Dakota, Oregon, Rhode Island, South Dakota, Utah, Vermont, West Virginia, Wyoming, and U.S. Virgin Islands. In all 13 states and the territory, field-test items were administered as unscored items embedded within the operational items.

In 2023, items were field-tested in 12 states and one U.S. territory: Connecticut, Hawaii, Idaho, Montana, New Hampshire, North Dakota, Oregon, Rhode Island, South Dakota, Utah, West Virginia, Wyoming, and U.S. Virgin Islands. Field-test items were administered as unscored items embedded within the operational items. CAI's field-test process is described in detail in Section 3.2, Field-Testing, in Volume 1 of this technical report.

2.7 Post-Field-Test Review

Following field testing, items are subject to a substantial validation process. This includes rubric validation and data review. These processes are described in Section 2.7.1, Rubric Validation, and Section 2.7.2, Data Review.

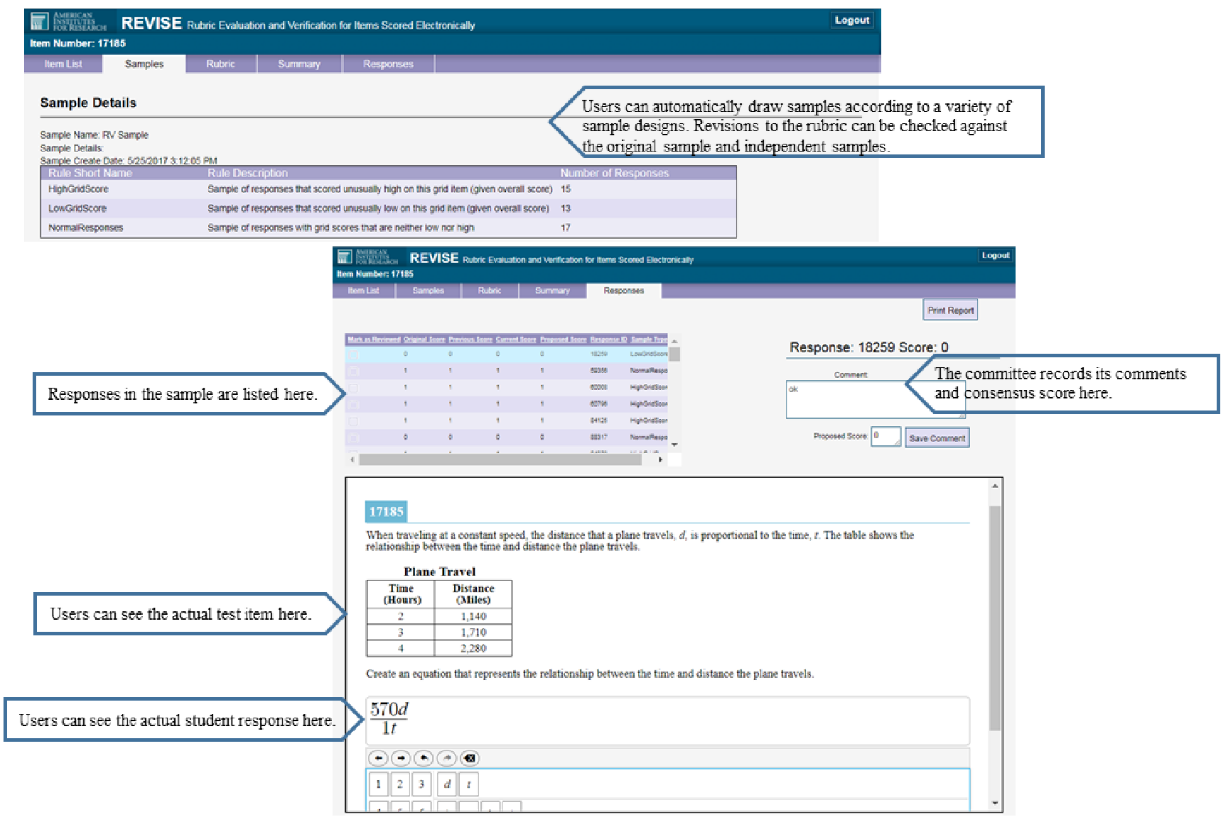
2.7.1 Rubric Validation

The validation process for the field-test items begins with rubric validation to verify and make any necessary revisions to the scoring rubrics. The rubric validation process occurs in two phases. During the first phase, CAI content experts work with the analysis team to prepare for the rubric validation meetings. The CAI content experts use the Rubric Evaluation and Verification for Items Scored Electronically (REVISE) system to generate student responses that are scientifically sampled to overrepresent responses most likely to have been mis-scored. Specifically, the sample overrepresents: low-scored responses from otherwise high-scoring students and high scored responses from otherwise low-scoring students. This process allows CAI to identify any potential scoring concerns before the rubric validation meeting, such as unanticipated (but accurate) responses, equivalent responses that were not originally considered, and responses receiving credit but should not (based on the content and the item rubric). At this point, the rubrics may be adjusted, and responses rescored.

The second phase of rubric validation involves committees of educators in each state or territory. The committees review the response samples generated by CAI to make recommendations to change or to confirm the rubrics of each item. The committee recommendations are then discussed with the state or territory of ownership to resolve any inconsistencies. The rubric is then edited or confirmed based on this resolution.

Figure 4 illustrates the features provided by the REVISE system.

Figure 4. Features of the REVISE Software



After the rubric validation meetings, CAI staff apply the approved revisions to the rubrics, and any items rejected as part of the process are rejected in the ITS. During this process, ITS archives critical information regarding the scoring certification completed during the rubric validation process. This includes any rubric changes made during the scoring decision meetings and the sign-off completed by the senior content expert once the rubric has been changed, rescoring the entire sample, and verifying that the final rubric functioned as intended.

Following rubric validation, all items are subject to statistical checks, and flagged items are presented in data review committees.

2.7.2 Data Review

Following rubric validation, all items are rescored and classical item statistics are computed for the scoring assertions, including item difficulty and item discrimination statistics, testing time, and differential item functioning (DIF) statistics. The states and U.S. territory established standards for the statistics, and any items violating these standards are flagged for a second educator review. Even though the scoring assertions are the basic units of analysis to compute classical item statistics, the business rules to flag items for additional educator review are established at the item level because assertions cannot be reviewed in isolation. A common set of business rules is defined for all the states participating in the field test. The classical item statistics are computed on the data of the students testing in the state that owned the item. For ICCR items administered in spring 2023, the data from students testing in Connecticut, Idaho, New Hampshire, North Dakota, Oregon, Rhode Island, South Dakota, Utah, and West Virginia were combined (states that administered ICCR items and used either an independent field test or operational test).

Section 4 of Volume 1, Field-Test Classical Analysis, describes the statistical flags that designate items for data review. The flags are designed to highlight potential content weaknesses, miskeys, or possible bias issues. Committee members are taught to interpret these flags and are given guidelines for examining the items for content or fairness issues.

For each of the states and participating in the MOU, flagged items owned by the state are reviewed by a data review committee. The composition of the data review committees generally includes content experts from the state's department of education or state educators (in this case, the state educators are science teachers) and are supported by CAI content experts. ICCR field-test items were taken to committee members from several states participating in the MOU. The outcomes are decided by CAI science content leadership while taking the committees' recommendations into consideration.

At the start of each state-owned item data review meeting, CAI staff leads participants in a training session to familiarize them with the item development process, the purpose of the data review committee and the data review process, and the meaning of the various flags. Committee members are taught to interpret the various flags and are given guidelines for examining the items for content or fairness issues. The training includes a group review of item cards, which detail specific item attributes (e.g., grade level and alignment to the science standard, the content and rubric of the item, and various item statistics). A sample of the training materials used for these data review meetings is presented in *Appendix 2-G, Sample Data Review Training Materials*. Participants use an online environment via laptop computers to review the items and interact with them in a manner similar to that of students, and to view the statistics associated with each item.

The items are then reviewed by the participants who are most familiar with the particular grade-band level and the items' content domain. CAI content specialists, who are also well versed in item statistics, facilitate the discussion in each room with CAI psychometricians available to answer questions as they arise. At the end of each meeting day, CAI content specialists meet with the state content specialists to review the committee recommendations and decide whether to accept or reject the item for inclusion in the operational pool. Items that were rejected become eligible for potential changes and may become additional field-test items in future administrations.

Table 5 summarizes the data review committee meetings. Details, including the composition of each committee, are presented in *Appendix 2-H, Data Review Committee Participant Details*.

Table 5. Summary of Data Review Committee Meetings

State/ Item Bank	Meeting	Number of Committee Members	Item Type	Number of Items Reviewed	Number of Items Rejected
Connecticut	August 2018	29	Cluster	7	5
			Stand-Alone	11	6
	August 2019	29	Cluster	14	6
			Stand-Alone	39	11
	August 2021	19	Cluster	8	2
			Stand-Alone	43	10
	August 2022	15	Cluster	5	4
			Stand-Alone	14	2
	September 2023	12	Cluster	11	4
			Stand-Alone	32	17
Hawaii	August 2018	18	Cluster	7	1
			Stand-Alone	25	2
	August 2019	18	Cluster	17	5
			Stand-Alone	20	8
	August 2021[a]	25	Cluster	6	0
			Stand-Alone	20	8
	August 2022[a]	12	Cluster	11	2
			Stand-Alone	38	6
	August 2023[a]	15	Cluster	3	2
			Stand-Alone	23	3
ICCR	July 2018	18	Cluster	33	2
			Stand-Alone	51	6
	August 2019[b]	–	Cluster	0	1
			Stand-Alone	43	2
	August 2021[a]	25	Cluster	11	2
			Stand-Alone	64	4
	August 2022[a]	20	Cluster	12	1
			Stand-Alone	56	13
	August 2023[a]	19	Cluster	12	1
			Stand-Alone	42	8
Idaho	August 2019	10	Cluster	4	3
			Stand-Alone	8	3
	August 2021[a]	25	Cluster	26	1
			Stand-Alone	34	4
	August 2022[a]	8	Cluster	3	0
			Stand-Alone	1	0
	August 2023[a]	17	Cluster	2	0
			Stand-Alone	3	0
Montana	September 2021	4	Cluster	3	2
			Stand-Alone	14	2
	September 2022	5	Cluster	5	2
			Stand-Alone	12	1
	August 2023[a]	11	Cluster	2	1

State/ Item Bank	Meeting	Number of Committee Members	Item Type	Number of Items Reviewed	Number of Items Rejected
			Stand-Alone	10	2
Multi-State Science Assessment (Rhode Island and Vermont)	August 2018	–	Cluster	2	0
			Stand-Alone	7	6
	August 2019	–	Cluster	2	1
			Stand-Alone	12	3
	August 2021	–	Cluster	4	4
			Stand-Alone	14	5
	September 2022	–	Cluster	1	1
			Stand-Alone	10	6
Oregon	September 2018	11	Cluster	28	5
			Stand-Alone	16	1
	August 2019	4	Cluster	1	1
			Stand-Alone	7	6
	August 2022[a]	8	Cluster	11	2
			Stand-Alone	20	6
			Legacy Stand-Alone	*9*	*4*
	August 2023[a]	16	Cluster	9	1
			Stand-Alone	3	1
			Legacy Stand-Alone	*24*	*11*
Rhode Island	September 2023	–	Cluster	7	2
			Stand-Alone	10	4
South Dakota	September 2021	–	*Legacy Stand-Alone*	*15*	*0*
	September 2022	–	*Legacy Stand-Alone*	*4*	*1*
	September 2023	–	*Legacy Stand-Alone*	*6*	*2*
Utah	August 2018	16	Cluster	40	6
	September 2021	6	Cluster	11	3
	September 2022	13	Cluster	11	6
	September 2023	20	Cluster	6	0
West Virginia	July 2018	4	Cluster	3	1
			Stand-Alone	0	0
	September 2019	4	Cluster	1	1
			Stand-Alone	6	5
	August 2021[a]	25	Cluster	1	1
			Stand-Alone	6	2
	August 2022[a]	9	Cluster	4	2
			Stand-Alone	6	2
	August 2023[a]	11	Cluster	2	1
			Stand-Alone	10	2
Wyoming	October 2018	12	Cluster	6	1
			Stand-Alone	10	5
	August 2019	10	Cluster	4	3
			Stand-Alone	12	2
	August 2021[a]	25	Cluster	3	1
			Stand-Alone	13	3
	August 2022[a]	12	Cluster	2	0
			Stand-Alone	17	3
	August 2023[a]	17	Cluster	3	0
			Stand-Alone	5	1

Note. MSSA, Rhode Island, and South Dakota-owned items were reviewed by Rhode Island Department of Education and Vermont Agency of Education science content experts, the Rhode Island Department of Education, and the South Dakota Department of Education, respectively.
[a]Combined Item Data Review Meetings were conducted for multiple states in 2021, 2022, and 2023 (184 items were reviewed in the combined meeting format for Hawaii, Idaho, West Virginia, Wyoming, and ICCR items in 2021; 181 items were reviewed in the combined meeting format for Hawaii, Idaho, Oregon, West Virginia, Wyoming, and ICCR items in 2022, and 129 items were reviewed in the combined meeting format for Hawaii, Idaho, Montana, Oregon, West Virginia, Wyoming, and ICCR items in 2023). In 2021, 25 committee members took part in the combined Item Data Review Meetings; in 2022, 38 committee members participated in the combined Item Data Review Meetings, and in 2023, 41 committee members participated in the combined Item Data Review Meetings. Items reviewed in the combined meetings are displayed by their respective state or bank of ownership.
[b]During the summer 2019, ICCR field-test items underwent committee review in Connecticut, Hawaii, and Idaho.

3. Shared Science Assessment Item Bank Summary

Tests based on *A Framework for K–12 Science Education* (National Research Council, 2012) adopt a three-dimensional conceptualization of science understanding, including crosscutting concepts (CCCs), science and engineering practices (SEPs), and disciplinary core ideas (DCIs). Accordingly, the new science assessments are composed mostly of item clusters representing a series of interrelated student interactions directed towards describing, explaining, and predicting scientific phenomena. Some stand-alone items are added to increase the coverage of the test without increasing the testing time or testing burden.

CAI has built the Shared Science Assessment Item Bank in partnership with multiple states and one U.S. territory. The science item bank is robust and has been constructed to support multiple statewide science assessments. As described earlier, science items are written to the three-dimensional science standards. The Shared Science Assessment Item Bank comprises ICCR items and items developed for specific states, which are all shared with MOU partner states. These items follow the same specifications, test development processes, and review processes.

In 2018, CAI field-tested more than 540 item clusters and stand-alone items, of which 451 (including items from all sources) were accepted and made available as operational items in 2019. In 2019, 347 item clusters and stand-alone items were field-tested, of which 268 were accepted and made available as operational items in 2020. In 2021, CAI field-tested 545 item clusters and stand-alone items, of which 458 have passed rubric validation and item data review. In 2022, CAI field tested 471 item clusters and stand-alone items, of which 403 have passed rubric validation and item data review. In 2023, CAI field-tested 348 item clusters and stand-alone items, of which 288 have passed rubric validation and item data review.

Each partnered user of the Shared Science Assessment Item Bank selects items that are appropriately aligned and have passed required reviews (as described in Section 2, Item Development Process That Supports Validity of Claims) for use on its statewide assessment. The Shared Science Assessment Item Bank continues to grow as participating states and territory continue to field-test new items. These participating partners collectively share the items and agree to field-test new items each year.

3.1 CURRENT COMPOSITION OF THE SHARED SCIENCE ASSESSMENT ITEM BANK

The Shared Science Assessment Item Bank contains item clusters and stand-alone items. Item clusters represent a series of interrelated student interactions directed toward describing, explaining, and predicting scientific phenomena. Item clusters can consist of several item parts requiring the student to interact with the item in various ways. In addition, shorter items (stand-alone items) are included to increase the coverage of the assessments without also increasing testing time or testing burden.

Within each item (item cluster and stand-alone item), a series of explicit assertions is made about the knowledge and skills that a student has demonstrated based on specific features of the student's responses across multiple interactions. For example, a student may correctly graph data points indicating that they can construct a graph showing the relationship between two variables, but they may make an incorrect inference about the relationship between the two variables, therefore not supporting the assertion that the student can interpret relationships expressed graphically. Table 6 lists and describes the science interaction types. Examples of various interaction types can be found in *Appendix 2-I, Example Item Interactions*.

Table 6. Science Interaction Types and Descriptions

Interaction Type	Associated Sub-Types	Description
Choice	Multiple-Choice	Traditional multiple-choice interaction allows students to select a single option from a list of possible answer options.
	Multi-Select	Traditional multi-select interaction (checkboxes) allows students to select one or more options from a list of possible answer choices.
Text Entry	Simple Text Entry	Students type a response in a text box.
	Embedded Text Entry	Students type their response in one or more text boxes that are embedded in a section of read-only text.
	Natural Language	Students are directed to provide a short, written response.
	Extended-Response	Students are directed to provide a longer, written response in the form of an essay.
Table	Table Match	Interaction allows students to check a box to indicate if the information from a column header matches information from a row header.
	Table Input	Interaction solicits students to complete tabular data.
Edit Task	Edit Task	Students click a word and replace it with another word that they type to revise a sentence.
	Edit Task with Choice	Students click a word or phrase and select the replacement from several options.
	Edit Task Inline Choice	Drop-down menus are placed throughout the text, and students select an option to complete the text.
Hot-Text	Selectable	Selectable hot-text interactions require students to select one or more text elements in the response area.
	Re-orderable	Re-orderable hot-text interactions require students to click and drag hot-text elements into a different order.

Interaction Type	Associated Sub-Types	Description
	Drag-from-Palette	Drag-from-Palette hot-text interactions require students to drag elements from a palette into the available blank table cells or "gaps" (text boxes) in the response area.
	Custom	Custom hot-text interactions combine the functionality of the other hot-text interaction sub-types. Students responding to a custom hot-text interaction may need to select text elements, rearrange text elements, and/or drag text elements from a palette to blank table cells or drop targets in the response area.
Equation	N/A	Equation interactions require students to enter a response into input boxes. These boxes may stand alone, or they may be in line with text or embedded in a table. The equation interaction may have an on-screen keypad which may consist of special mathematic characters. Students may also enter their response via a physical keyboard.
Grid	Grid	Grid interactions require students to enter a response by interacting with a grid area in the answer space. The student may be required to draw a line or shape, plot a point, or create a graph. The student may also drag and drop or click on selectable hot-spots.
	Hot-Spot	Hot-spot interaction sub-types facilitate grid interactions with specific hot-spot functionality. These interactions require students to select hot-spot regions in the grid area.
	Graphic Gap Match	Graphic gap match interactions facilitate grid interactions with specific drag-and-drop functionality. These interactions require students to drag image objects from a palette to specified regions (gaps) in the grid area.
Simulation	N/A	Simulation interactions allow students to investigate a phenomenon by selecting variables to get output data. Some simulations are accompanied by animations.

Table 7–Table 11 present the number of items in the Shared Science Assessment Item Bank available for use in the spring 2023 statewide assessments. *Appendix 2-J, Shared Science Assessment Item Bank*, provides the items available within the bank by grade band, performance standards and origin.

Table 7. Spring 2023 Shared Science Assessment Operational and Field-Test Item Bank

Grade Band and Item Type	ICCR Items	Idaho Items	MOU Items*	Total Bank Items
Elementary School	**174**	**46**	**457**	**677**
Cluster	66	23	258	347
Stand-Alone	108	23	199	330
Middle School	**188**	**47**	**457**	**692**
Cluster	74	23	239	336
Stand-Alone	114	24	218	356
High School	**154**	**42**	**295**	**491**

Grade Band and Item Type	ICCR Items	Idaho Items	MOU Items*	Total Bank Items
Cluster	56	24	127	207
Stand-Alone	98	18	168	284
Total	**516**	**135**	**1209**	**1860**

*Other MOU states include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming.

Table 8. Spring 2023 Shared Science Assessment Operational Item Bank

Grade Band and Item Type	ICCR Operational Items	Idaho Operational Items	MOU Operational Items*	Total Bank Operational Items
Elementary School	**139**	**41**	**371**	**551**
Cluster	49	20	218	287
Stand-Alone	90	21	153	264
Middle School	**147**	**43**	**366**	**556**
Cluster	53	20	204	277
Stand-Alone	94	23	162	279
High School	**131**	**39**	**235**	**405**
Cluster	50	22	95	167
Stand-Alone	81	17	140	238
Total	**417**	**123**	**972**	**1512**

*Other MOU operational item states include Connecticut, Hawaii, Rhode Island, Oregon, Utah, West Virginia, and Wyoming.

Table 9. Spring 2023 Shared Science Assessment Field-Test Item Bank

Grade Band and Item Type	ICCR Field-Test Items	Idaho Field-Test Items	MOU Field-Test Items*	Total Bank Field-Test Items
Elementary School	**35**	**5**	**86**	**126**
Cluster	17	3	40	60
Stand-Alone	18	2	46	66
Middle School	**41**	**4**	**91**	**136**
Cluster	21	3	35	59
Stand-Alone	20	1	56	77
High School	**23**	**3**	**60**	**86**
Cluster	6	2	32	40
Stand-Alone	17	1	28	46
Total	**99**	**12**	**237**	**348**

*Other MOU field-test item states include Connecticut, Hawaii, Montana, Rhode Island, Utah, West Virginia, and Wyoming.

Table 10. Spring 2023 Shared Science Assessment Operational and Field-Test Item Bank by Science Discipline

Grade Band	Science Discipline	Item Type	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
Elementary School	Earth and Space Sciences	Cluster	23	7	84	114
		Stand-Alone	31	8	60	99
	Life Sciences	Cluster	21	6	75	102
		Stand-Alone	37	7	58	102
	Physical Sciences	Cluster	22	10	99	131
		Stand-Alone	40	8	81	129
Middle School	Earth and Space Sciences	Cluster	22	6	60	88
		Stand-Alone	30	7	67	104
	Life Sciences	Cluster	29	6	97	132
		Stand-Alone	50	8	79	137
	Physical Sciences	Cluster	23	9	77	109
		Stand-Alone	34	8	72	114
High School	Earth and Space Sciences	Cluster	15	4	29	48
		Stand-Alone	24	4	43	71
	Life Sciences	Cluster	22	6	64	92
		Stand-Alone	44	4	73	121
	Physical Sciences	Cluster	19	13	34	66
		Stand-Alone	30	10	52	92
Total			**516**	**131**	**1204**	**1851**

[a]Other MOU states include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming.
[b]Count excludes nine MOU items that do not align to the NGSS.

Table 11. Spring 2023 Shared Science Assessment Operational and Field-Test Item Bank by Disciplinary Core Idea

Grade Band	Science Discipline	Disciplinary Core Idea	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
Elementary School	Earth and Space Sciences	ESS1	11	3	41	55
		ESS2	19	8	66	93
		ESS3	24	4	37	65
	Life Sciences	LS1	22	3	51	76
		LS2	6	3	27	36
		LS3	7	2	20	29
		LS4	23	5	35	63
	Physical Sciences	PS1	14	6	41	61
		PS2	22	4	39	65
		PS3	19	6	62	87
		PS4	7	2	38	47
Middle School	Earth and Space Sciences	ESS1	14	5	35	54
		ESS2	22	3	44	69
		ESS3	16	5	48	69
	Life Sciences	LS1	27	5	62	94
		LS2	26	2	48	76
		LS3	6	2	17	25
		LS4	20	5	49	74
	Physical Sciences	PS1	18	4	47	69
		PS2	8	6	45	59
		PS3	20	4	34	58
		PS4	11	3	23	37
High School	Earth and Space Sciences	ESS1	14	3	19	36
		ESS2	12	3	30	45
		ESS3	13	2	23	38
	Life Sciences	LS1	19	2	42	63
		LS2	21	2	44	67
		LS3	8	2	18	28
		LS4	18	4	33	55
	Physical Sciences	PS1	19	7	30	56

Grade Band	Science Discipline	Disciplinary Core Idea	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
		PS2	10	6	20	36
		PS3	11	5	23	39
		PS4	9	5	13	27
Total			**516**	**131**	**1204**	**1851**

[a]Other MOU states include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming. [b]Count excludes nine MOU items that do not align to the NGSS.

3.2 Strategy for Item Bank Evaluation and Replenishment

Both CAI and the participating MOU states continue to develop items to replenish and grow the Shared Science Assessment Item Bank. The general strategy for targeting item development gathers information from the following three sources:

1. Characteristics of released items to be replaced
2. Characteristics of items that are overused
3. Tabulations of content coverage and ranges of difficulty to identify gaps in the bank

Before a test goes live, simulations are used to fine-tune the parameters of the algorithm that govern the item selection in an adaptive test design. Among the many reports from the simulator are items that are seen by more than 20% of students. The characteristics of these items are the primary targets for development. Overused items become candidates for release in two years once replacements have been introduced into the operational bank.

4. Test Construction for the Idaho Standards Achievement Test in Science

4.1 Test Design

The ISAT in Science was administered online to students in grades 5, 8, and 11 using an adaptive testing design in spring 2023. In an adaptive test, operational items are selected on the fly based on the performance of a student on past items while ensuring the test blueprint is followed for each individual student. An advantage of adaptive testing is that it can provide more precise scores for students with lower and higher proficiencies, in contrast to fixed forms and linear-on-the fly tests (LOFTs) that are typically targeted to provide the best precision for students with medium proficiencies. Also, as opposed to a fixed form and a LOFT, every student has the potential to see a different set of items that adapt to the student's ability, thus offering a better testing experience.

Items are selected by an item-selection algorithm based on the content and information value. At any given point during the test, the content value of an item is determined by its contribution to meeting the blueprint, given the content characteristics of the items that have already been administered. During the test, the content value increases for items that exhibit features that have not met their designated minimum as the end of the test approaches. Conversely, the content value decreases for items with content features that met the minimum. The information value of an item is based on the item information function evaluated at the estimated proficiency. The proficiency estimate is updated throughout the test.

The adaptive item-selection algorithm is the same algorithm CAI uses to deliver English language arts (ELA) and mathematics tests, but with some modifications to make it suitable for using item clusters. Specifically, the proficiencies that are estimated during the test are computed under an item response theory (IRT) model that incorporates cluster effects. In order to avoid over-selection of items with many scoring assertions, the information of an item at an estimated proficiency level is normalized by the number of assertions in the item (similar to how information is computed for item sets in ELA and mathematics assessments).

A non-segmented test design was used for the ISAT in Science, meaning students received items from different disciplines in a random order. Compared to the use of a segmented design where items are administered by science discipline, the use of a non-segmented test design provides more freedom when selecting items targeting a current best estimate of proficiency in an adaptive test. Embedded field-test items were randomly positioned in the test and randomly distributed across students. Every student received either one item cluster or four stand-alone items as field-test items throughout the test.

4.2 TEST BLUEPRINTS

Test blueprints provide the following guidelines:

- Test length
- Science disciplines to be covered and the acceptable number of items across performance standards within each science discipline and Disciplinary Core Idea (DCI)

The blueprint for science is presented in Table 12 –Table 14.

Table 12. Science Test Blueprint, Grade 5

Grade 5	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
Discipline- Physical Sciences, Standard Total = 17	**2**	**2**	**4**	**4**	**6**	**6**
DCI- Motion and Stability: Forces and Interactions	**0**	**1**	**0**	**2**	**0**	**3**
PS1-3-1: Forces and Motion & Types of Interactions	0	1	0	1	0	1
PS1-3-2: Forces and Motion	0	1	0	1	0	1
PS1-3-3: Types of Interactions	0	1	0	1	0	1
PS1-3-4: Types of Interactions*	0	1	0	1	0	1
PS2-5-1: Types of Interactions	0	1	0	1	0	1
DCI- Energy	**0**	**1**	**0**	**2**	**0**	**3**
PS1-4-1: Definitions of Energy	0	1	0	1	0	1
PS1-4-2: Definitions of Energy & Conservation of Energy and Energy Transfer	0	1	0	1	0	1
PS1-4-3: Definitions of Energy & Conservation of Energy and Energy Transfer & Relationship Between Energy and Forces	0	1	0	1	0	1
PS1-4-4: Conservation of Energy and Energy Transfer & Energy in Chemical Processes and Everyday Life & Defining Engineering Problems*	0	1	0	1	0	1
PS3-5-1: Energy in Chemical Processes and Everyday Life & Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
DCI- Waves	**0**	**1**	**0**	**2**	**0**	**3**
PS2-4-1: Wave Properties	0	1	0	1	0	1
PS2-4-2: Electromagnetic Radiation	0	1	0	1	0	1
PS2-4-3: Information Technologies and Instrumentation & Optimizing the Design Solution*	0	1	0	1	0	1
DCI- Matter and Its Interactions	**0**	**1**	**0**	**2**	**0**	**3**

Grade 5	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
PS1-5-1: Structure and Properties of Matter	0	1	0	1	0	1
PS1-5-2: Structure and Properties of Matter & Chemical Reactions	0	1	0	1	0	1
PS1-5-3: Structure and Properties of Matter	0	1	0	1	0	1
PS1-5-4: Chemical Reactions	0	1	0	1	0	1
Discipline- Life Sciences, Standard Total = 11	**2**	**2**	**4**	**4**	**6**	**6**
DCI- From Molecules to Organisms: Structure and Function	**0**	**1**	**0**	**2**	**0**	**3**
LS1-4-1: Structure and Function	0	1	0	1	0	1
LS1-4-2: Information Processing	0	1	0	1	0	1
LS1-5-1: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
DCI- Ecosystems: Interactions, Energy, and Dynamics	**0**	**1**	**0**	**2**	**0**	**3**
LS1-3-1: Social Interactions and Group Behavior	0	1	0	1	0	1
LS2-4-1: Interdependent Relationships in Ecosystems & Cycles of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1
DCI- Heredity: Inheritance and Variation of Traits	**0**	**1**	**0**	**2**	**0**	**3**
LS2-3-1: Inheritance of Traits & Variation of Traits	0	1	0	1	0	1
LS2-3-2: Inheritance of Traits & Variation of Traits	0	1	0	1	0	1
DCI- Biological Adaptation: Unity and Diversity	**0**	**1**	**0**	**2**	**0**	**3**
LS2-5-1: Evidence of Common Ancestry and Diversity	0	1	0	1	0	1
LS2-5-2: Natural Selection & Biodiversity and Humans	0	1	0	1	0	1
LS2-5-3: Adaptation	0	1	0	1	0	1

Grade 5	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
LS2-5-4: Ecosystem Dynamics, Functioning, and Resilience & Biodiversity and Humans*	0	1	0	1	0	1
Discipline- Earth and Space Sciences, Standard Total = 13	**2**	**2**	**4**	**4**	**6**	**6**
DCI- Earth's Systems	**0**	**1**	**0**	**2**	**0**	**3**
ESS1-3-1: Weather and Climate	0	1	0	1	0	1
ESS1-3-2: Weather and Climate	0	1	0	1	0	1
ESS2-4-1: Earth Materials and Systems & Biogecology	0	1	0	1	0	1
ESS2-4-2: Plate Tectonics and Large-Scale System Interactions	0	1	0	1	0	1
ESS2-5-1: Earth Materials and Systems	0	1	0	1	0	1
ESS2-5-2: The Roles of Water in Earth's Surface Processes	0	1	0	1	0	1
DCI- Earth and Human Activity	**0**	**1**	**0**	**2**	**0**	**3**
ESS2-3-1: Natural Hazards*	0	1	0	1	0	1
ESS3-4-2: Natural Hazards & Designing Solutions to Engineering Problems*	0	1	0	1	0	1
ESS3-4-1: Natural Resources	0	1	0	1	0	1
ESS3-5-1: Human Impacts on Earth Systems	0	1	0	1	0	1
DCI- Earth's Place In the Universe	**0**	**1**	**0**	**2**	**0**	**3**
ESS1-4-1: The History of Planet Earth	0	1	0	1	0	1
ESS1-5-1: The Universe and its Stars	0	1	0	1	0	1
ESS1-5-2: Earth and the Solar System	**0**	**1**	**0**	**1**	**0**	**1**
Standard Total = 41	**6**	**6**	**12**	**12**	**18**	**18**

*These standards have an engineering component.

Table 13. Science Test Blueprint, Grade 8

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
Discipline—Physical Sciences, Standard Total = 19	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Matter and Its Interactions	**0**	**1**	**0**	**2**	**0**	**3**
PS1-MS-1: Structure and Properties of Matter & Chemical Reactions	0	1	0	1	0	1
PS1-MS-2: Structure and Properties of Matter	0	1	0	1	0	1
PS1-MS-3: Structure and Properties of Matter & Chemical Reactions	0	1	0	1	0	1
PS1-MS-4: Structure and Properties of Matter & Definitions of Energy	0	1	0	1	0	1
PS1-MS-5: Chemical Reactions	0	1	0	1	0	1
PS1-MS-6: Chemical Reactions & Definitions of Energy & Developing Possible Solutions*	0	1	0	1	0	1
DCI—Motion and Stability: Forces and Interactions	**0**	**1**	**0**	**2**	**0**	**3**
PS2-MS-1: Forces and Motion*	0	1	0	1	0	1
PS2-MS-2: Forces and Motion	0	1	0	1	0	1
PS2-MS-3: Types of Interactions	0	1	0	1	0	1
PS2-MS-4: Types of Interactions	0	1	0	1	0	1
PS2-MS-5: Types of Interactions	0	1	0	1	0	1
DCI—Energy	**0**	**1**	**0**	**2**	**0**	**3**
PS3-MS-1: Definitions of Energy	0	1	0	1	0	1
PS3-MS-2: Definitions of Energy & Relationship Between Energy and Forces	0	1	0	1	0	1
PS3-MS-3: Definitions of Energy & Conservation of Energy and Energy Transfer & Defining and Delimiting an Engineering Problem & Developing Possible Solutions*	0	1	0	1	0	1

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
PS3-MS-4: Definitions of Energy & Conservation of Energy and Energy Transfer	0	1	0	1	0	1
PS3-MS-5: Conservation of Energy and Energy Transfer	0	1	0	1	0	1
DCI—Waves	**0**	**1**	**0**	**2**	**0**	**3**
PS4-MS-1: Wave Properties	0	1	0	1	0	1
PS4-MS-2: Wave Properties & Electromagnetic Radiation	0	1	0	1	0	1
PS4-MS-3: Information Technologies and Instrumentation	0	1	0	1	0	1
Discipline—Life Sciences, Standard Total = 20	**2**	**2**	**4**	**4**	**6**	**6**
DCI—From Molecules to Organisms: Structures and Processes	**0**	**1**	**0**	**2**	**0**	**3**
LS1-MS-1: Structure and Function	0	1	0	1	0	1
LS1-MS-2: Structure and Function	0	1	0	1	0	1
LS1-MS-3: Structure and Function	0	1	0	1	0	1
LS1-MS-4: Characteristics of Living Things	0	1	0	1	0	1
LS1-MS-5: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
LS1-MS-6: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
DCI—Ecosystems: Interactions, Energy, and Dynamics	**0**	**1**	**0**	**2**	**0**	**3**
LS2-MS-1: Interdependent Relationships in Ecosystems	0	1	0	1	0	1
LS2-MS-2: Interdependent Relationships in Ecosystems	0	1	0	1	0	1
LS2-MS-3: Cycle of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
LS2-MS-4: Cycle of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1
LS2-MS-5: Ecosystem Dynamics, Functioning, and Resilience	0	1	0	1	0	1
LS2-MS-6: Ecosystem Dynamics, Functioning, and Resilience & Biodiversity and Humans & Developing Possible Solutions*	0	1	0	1	0	1
DCI—Heredity: Inheritance and Variation of Traits	**0**	**1**	**0**	**2**	**0**	**3**
LS3-MS-1: Inheritance of Traits & Variance of Traits	0	1	0	1	0	1
LS3-MS-2: Growth and Development of Organisms & Inheritance of Traits & Variation of Traits	0	1	0	1	0	1
DCI—Biological Evolution: Unity and Diversity	**0**	**1**	**0**	**2**	**0**	**3**
LS4-MS-1: Classification of Organisms	0	1	0	1	0	1
LS4-MS-2: Classification of Organisms	0	1	0	1	0	1
LS4-MS-3: Classification of Organisms	0	1	0	1	0	1
LS4-MS-4: Natural Selection	0	1	0	1	0	1
LS4-MS-5: Natural Selection	0	1	0	1	0	1
LS4-MS-6: Adaptation	0	1	0	1	0	1
Discipline—Earth and Space Sciences, Standard Total = 15	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Earth's Place in the Universe	**0**	**1**	**0**	**2**	**0**	**3**
ESS1-MS-1: The Universe and Its Stars & Earth and the Solar System	0	1	0	1	0	1
ESS1-MS-2: The Universe and Its Stars & Earth and the Solar System	0	1	0	1	0	1
ESS1-MS-3: Earth and the Solar System	0	1	0	1	0	1
ESS1-MS-4: History of Earth	0	1	0	1	0	1
DCI—Earth's Systems	**0**	**1**	**0**	**2**	**0**	**3**

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
ESS2-MS-1: Earth's Materials and Systems	0	1	0	1	0	1
ESS2-MS-2: Earth's Earth's Materials and Systems & The Roles of Water in Earth's Surface Processes	0	1	0	1	0	1
ESS2-MS-3: History of the Planet Earth & Plate Tectonics and Large-Scale System Interactions	0	1	0	1	0	1
ESS2-MS-4: The Roles of Water in Earth's Surface Processes	0	1	0	1	0	1
ESS2-MS-5: The Roles of Water in Earth's Surface Processes & Weather and Climate	0	1	0	1	0	1
ESS2-MS-6: Weather and Climate	0	1	0	1	0	1
DCI—Earth and Human Activity	**0**	**1**	**0**	**2**	**0**	**3**
ESS3-MS-1: Natural Resources	0	1	0	1	0	1
ESS3-MS-2: Natural Hazards	0	1	0	1	0	1
ESS3-MS-3: Human Impacts on Earth Systems*	0	1	0	1	0	1
ESS3-MS-4: Human Impacts on Earth Systems	0	1	0	1	0	1
ESS3-MS-5: Human Impacts on Earth Systems	0	1	0	1	0	1
Total Standards = 54	**6**	**6**	**12**	**12**	**18**	**18**

*These standards have an engineering component.

Table 14. Science Test Blueprint, Grade 11

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
Discipline—Physical Sciences (Chemistry and Physics), Standard Total = 31	**2**	**2**	**5**	**5**	**7**	**7**
DCI—Structure and Properties of Matter & Chemical Reactions (Chemistry)	**0**	**1**	**0**	**2**	**0**	**3**
PSC1-HS-1: Structure and Properties of Matter & Types of Interactions (Chemistry)	0	1	0	1	0	1
PSC1-HS-2: Structure and Properties of Matter & Types of Interactions (Chemistry)	0	1	0	1	0	1
PSC1-HS-3: Structure and Properties of Matter & Types of Interactions (Chemistry)	0	1	0	1	0	1
PSC1-HS-4: Nuclear Processes (Chemistry)	0	1	0	1	0	1
PSC1-HS-5: Structure and Properties of Matter & Types of Interactions (Chemistry)	0	1	0	1	0	1
PSC2-HS-1: Structure and Properties of Matter & Chemical Reactions (Chemistry)	0	1	0	1	0	1
PSC2-HS-2: Structure and Properties of Matter & Chemical Reactions (Chemistry)	0	1	0	1	0	1
PSC2-HS-3: Chemical Reactions (Chemistry)	0	1	0	1	0	1
PSC2-HS-4: Chemical Reactions (Chemistry)	0	1	0	1	0	1
PSC2-HS-5: Chemical Reactions & Optimizing the Design Solution (Chemistry)*	0	1	0	1	0	1
DCI—Energy (Chemistry)	**0**	**1**	**0**	**2**	**0**	**3**
PSC3-HS-1: Electromagnetic Radiation (Chemistry)	0	1	0	1	0	1
PSC3-HS-2: Definitions of Energy & Conservation of Energy and Energy Transfer (Chemistry)	0	1	0	1	0	1
PSC3-HS-3: Definitions of Energy (Chemistry)	0	1	0	1	0	1
PSC3-HS-4: Definitions of Energy & Energy in Chemical Processes (Chemistry)*	0	1	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
PSC3-HS-5: Conservation of Energy and Energy Transfer & Energy in Chemical Processes (Chemistry)*	0	1	0	1	0	1
DCI—Motion and Stability: Forces and Interactions (Physics)	**0**	**1**	**0**	**2**	**0**	**3**
PSP1-HS-1: Forces and Motion (Physics)	0	1	0	1	0	1
PSP1-HS-2: Forces and Motion (Physics)	0	1	0	1	0	1
PSP1-HS-3: Forces and Motion & Types of Interactions & Defining and Delimiting and Engineering Problem & Optimizing the Design Solution (Physics)*	0	1	0	1	0	1
PSP1-HS-4: Types of Interactions (Physics)	0	1	0	1	0	1
PSP1-HS-5: Types of Interactions & Definitions of Energy (Physics)	0	1	0	1	0	1
PSP1-HS-6 : Types of Interactions (Physics)*	0	1	0	1	0	1
DCI—Energy (Physics)	**0**	**1**	**0**	**2**	**0**	**3**
PSP2-HS-1: Definitions of Energy & Conservation of Energy and Energy Transfer (Physics)	0	1	0	1	0	1
PSP2-HS-2: Definitions of Energy (Physics)	0	1	0	1	0	1
PSP2-HS-3: Definitions of Energy & Energy in Chemical Processes & Defining and Delimiting an Engineering Problem (Physics)*	0	1	0	1	0	1
PSP2-HS-4: Conservation of Energy and Energy Transfer & Energy in Chemical Processes (Physics)	0	1	0	1	0	1
PSP2-HS-5: Relationship Between Energy and Forces (Physics)	0	1	0	1	0	1
DCI I—Waves (Physics)	0	1	0	2	0	3
PSP3-HS-1: Wave Properties (Physics)	0	1	0	1	0	1
PSP3-HS-2: Wave Properties (Physics)	0	1	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
PSP3-HS-3: Wave Properties & Electromagnetic Radiation (Physics)	0	1	0	1	0	1
PSP3-HS-4: Electromagnetic Radiation (Physics)	0	1	0	1	0	1
PSP3-HS-5: Energy in Chemical Processes & Wave Properties & Electromagnetic Radiation & Information Technologies and Instrumentation (Physics)*	0	1	0	1	0	1
Discipline—Life Sciences, Standard Total = 24	**2**	**2**	**4**	**4**	**6**	**6**
DCI—From Molecules to Organisms: Structures and Processes	**0**	**1**	**0**	**2**	**0**	**3**
LS1-HS-1: Structure and Function	0	1	0	1	0	1
LS1-HS-2: Structure and Function	0	1	0	1	0	1
LS1-HS-3: Structure and Function	0	1	0	1	0	1
LS1-HS-4: Growth and Development of Organisms	0	1	0	1	0	1
LS1-HS-5: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
LS1-HS-6: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
LS1-HS-7: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
DCI—Ecosystems: Interactions, Energy, and Dynamics	**0**	**1**	**0**	**2**	**0**	**3**
LS2-HS-1: Interdependent Relationships in Ecosystems	0	1	0	1	0	1
LS2-HS-2: Interdependent Relationships in Ecosystems & Ecosystem Dynamics, Functioning, and Resilience	0	1	0	1	0	1
LS2-HS-3: Cycles of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
LS2-HS-4: Cycles of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1
LS2-HS-5: Cycles of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1
LS2-HS-6: Ecosystem Dynamics, Functioning, and Resilience	0	1	0	1	0	1
LS2-HS-7: Ecosystem Dynamics, Functioning and Resilience & Biodiversity and Humans*	0	1	0	1	0	1
LS2-HS-8: Social Interactions and Group Behavior	0	1	0	1	0	1
DCI—Heredity: Inheritance and Variation of Traits	**0**	**1**	**0**	**2**	**0**	**3**
LS3-HS-1: Structure and Function & Inheritance of Traits	0	1	0	1	0	1
LS3-HS-2: Variation of Traits	0	1	0	1	0	1
LS3-HS-3: Variation of Traits	0	1	0	1	0	1
DCI—Biological Evolution: Unity and Diversity	**0**	**1**	**0**	**2**	**0**	**3**
LS4-HS-1: Evidence of Common Ancestry and Diversity	0	1	0	1	0	1
LS4-HS-2: Natural Selection & Adaptation	0	1	0	1	0	1
LS4-HS-3: Natural Selection & Adaptation	0	1	0	1	0	1
LS4-HS-4: Adaptation	0	1	0	1	0	1
LS4-HS-5: Adaptation	0	1	0	1	0	1
LS4-HS-6: Adaptation & Biodiversity and Humans & Developing Possible Solutions*	0	1	0	1	0	1
Discipline—Earth and Space Sciences, Standard Total = 19	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Earth's Place in the Universe	**0**	**1**	**0**	**2**	**0**	**3**
ESS1-HS-1: The Universe and Its Stars & Energy in Chemical Processes and Everyday Life	0	1	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
ESS1-HS-2: The Universe and Its Stars & Electromagnetic Radiation	0	1	0	1	0	1
ESS1-HS-3: The Universe and Its Stars	0	1	0	1	0	1
ESS1-HS-4: Earth and the Solar System	0	1	0	1	0	1
ESS1-HS-5: The History of Planet Earth & Plate Tectonics and Large-Scale System Interactions & Nuclear Processes	0	1	0	1	0	1
ESS1-HS-6: The History of Planet Earth & Nuclear Processes	0	1	0	1	0	1
DCI—Earth's Systems	**0**	**1**	**0**	**2**	**0**	**3**
ESS2-HS-1: Earth Materials and Systems & Plate Tectonics and Large-Scale System Interactions	0	1	0	1	0	1
ESS2-HS-2: Earth Materials and Systems & Weather and Climate	0	1	0	1	0	1
ESS2-HS-3: Earth Materials and Systems & Plate Tectonics and Large-Scale System Interactions & Wave Properties	0	1	0	1	0	1
ESS2-HS-4: Earth and the Solar System & Earth Materials and Systems & Weather and Climate	0	1	0	1	0	1
ESS2-HS-5: The Roles of Water in Earth's Surface Processes	0	1	0	1	0	1
ESS2-HS-6: Weather and Climate	0	1	0	1	0	1
ESS2-HS-7: Weather and Climate & Bioecology	0	1	0	1	0	1
DCI—Earth and Human Activity	**0**	**1**	**0**	**2**	**0**	**3**
ESS3-HS-1: Natural Resources & Natural Hazards	0	1	0	1	0	1
ESS3-HS-2: Natural Resources & Developing Possible Solutions*	0	1	0	1	0	1
ESS3-HS-3: Human Impacts on Earth Systems	0	1	0	1	0	1
ESS3-HS-4: Human Impacts on Earth Systems & Developing Possible Solutions*	0	1	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
ESS3-HS-5: Human Impacts on Earth Systems	0	1	0	1	0	1
ESS3-HS-6: Weather and Climate & Human Impacts on Earth Systems	0	1	0	1	0	1
Total Standards = 74	**6**	**6**	**13**	**13**	**19**	**19**

*These standards have an engineering component.

The main characteristics of the blueprint were that any performance standards could be tested only once (indicated by the values of 0 and 1 for the minimum and maximum values of the individual standards in Table 12–Table 14). In general, no more than one item cluster or two stand-alone items could be sampled from the same DCI, and no more than three total items could be sampled from the same DCI (as indicated by the minimum and maximum values in the rows representing DCIs).

While tests are not timed, the Idaho SDE published estimated testing times for the ISAT in Science. The 85th percentile of the testing times is presented in Table 15.

Table 15. ISAT in Science 85th Percentile Testing Times by Grade

Subject	Grade	85th Percentile Testing
Science	5	122.33
	8	97.32
	11	80.83

4.3 ONLINE TEST CONSTRUCTION

During fall 2022, CAI psychometricians and content experts worked with Idaho SDE content specialists and leadership to build item pools for the spring 2023 administration. The ISAT in Science test construction used a structured test construction plan, explicit blueprints, and active collaborative participation from all parties.

The 2023 ISAT in Science item pools were built by CAI test developers to match items exactly to the detailed test blueprints. Operational items were selected from 10 item banks (ICCR, Connecticut, Hawaii, Idaho, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming) to fulfill the blueprint for each grade. Table 16–Table 20 summarize the 2023 ISAT in Science item pool. *Appendix 2-K, Idaho Standards Achievement Test in Science Item Pool*, provides the 2023 item pool by grade band, achievement standard, and origin. Details of the adaptive testing algorithm by CAI to utilize the science pool are described in *Appendix 2-L, Adaptive Algorithm Design*.

Table 16. Spring 2023 ISAT in Science Operational and Field-Test Item Pool

Grade and Item Type	ICCR Items	Idaho Items	MOU Items[a]	Total Pool Items[b]
Grade 5	**116**	**46**	**166**	**328**
Cluster	41	23	93	157
Stand-Alone	75	23	73	171
Grade 8	**134**	**47**	**133**	**314**
Cluster	45	23	65	133
Stand-Alone	89	24	68	181
Grade 11	**120**	**42**	**124**	**286**
Cluster	45	24	63	132
Stand-Alone	75	18	61	154
Total	**370**	**135**	**423**	**928**

[a]Other MOU state items administered include Connecticut, Hawaii, Montana, MSSA (Rhode Island and Vermont), Oregon, Utah, West Virginia, and Wyoming. [b]The total count excludes three field-tested items intended for the interim pool.

Table 17. Spring 2023 ISAT in Science Operational Item Pool

Grade and Item Type	ICCR Operational Items	Idaho Operational Items	MOU Operational Items[*]	Total Operational Pool Items
Grade 5	**115**	**41**	**152**	**308**
Cluster	40	20	85	145
Stand-Alone	75	21	67	163
Grade 8	**126**	**43**	**124**	**293**
Cluster	43	20	65	128
Stand-Alone	83	23	59	165
Grade 11	**117**	**39**	**110**	**266**
Cluster	45	22	57	124
Stand-Alone	72	17	53	142
Total	**358**	**123**	**386**	**867**

[*]Other MOU state operational items administered include Connecticut, Hawaii, Montana, MSSA (Rhode Island and Vermont), Oregon, Utah, West Virginia, and Wyoming.

Table 18. Spring 2023 ISAT in Science Field-Test Item Pool

Grade and Item Type	ICCR Field-Test Items	Idaho Field-Test Items	MOU Field-Test Items[a]	Total Field-Test Pool Items[b]
Grade 5	**1**	**5**	14	**20**
Cluster	1	3	8	12
Stand-Alone	0	2	6	8
Grade 8	**8**	**4**	**9**	**21**
Cluster	2	3	0	5
Stand-Alone	6	1	9	16
Grade 11	**3**	**3**	**14**	**20**
Cluster	0	2	6	8
Stand-Alone	3	1	8	12
Total	**12**	**12**	**37**	**61**

Other MOU state field-test items administered include Connecticut, Hawaii, Montana, MSSA (Rhode Island and Vermont), Oregon, Utah, West Virginia, and Wyoming. [b]The total count excludes three field-tested items intended for the interim pool.

Table 19. Spring 2023 ISAT in Science Operational and Field-Test Item Pool by Science Discipline

Grade	Science Discipline	Item Type	ICCR Items	Idaho Items	MOU Items[a]	Total Pool Items[b]
5	Earth and Space Sciences	Cluster	15	7	21	43
		Stand-Alone	22	8	21	51
	Life Sciences	Cluster	10	6	28	44
		Stand-Alone	25	7	23	55
	Physical Sciences	Cluster	16	10	44	70
		Stand-Alone	28	8	29	65
8	Earth and Space Sciences	Cluster	15	6	21	42
		Stand-Alone	24	7	17	48
	Life Sciences	Cluster	16	8	24	48
		Stand-Alone	38	9	25	72
	Physical Sciences	Cluster	14	9	20	43
		Stand-Alone	27	8	26	61
11	Earth and Space Sciences	Cluster	11	4	15	30
		Stand-Alone	19	4	18	41
	Life Sciences	Cluster	19	6	30	55
		Stand-Alone	36	4	21	61
	Physical Sciences	Cluster	15	14	18	47
		Stand-Alone	20	10	22	52
Total			**370**	**135**	**423**	**928**

[a]Other MOU states items administered include Connecticut, Hawaii, Montana, MSSA (Rhode Island and Vermont), Oregon, Utah, West Virginia, and Wyoming. [b]The total count excludes three field-tested items intended for the interim pool.

Table 20. Spring 2023 ISAT in Science Operational and Field-Test Item Pool by Disciplinary Core Idea

Grade	Science Discipline	Disciplinary Core Idea	ICCR Items	Idaho Items	MOU Items[a]	Total Pool Items[b]
5	Earth and Space Sciences	ESS1	10	3	11	24
		ESS1/2	11	8	22	41
		ESS2/3	16	4	9	29
	Life Sciences	LS1	13	3	18	34
		LS1/2	5	3	13	21
		LS2-3	5	2	8	15
		LS2-5	12	5	12	29
	Physical Sciences	PS1	11	6	13	30
		PS1/2	13	4	16	33
		PS1/3	16	6	27	49
		PS2	4	2	17	23
8	Earth and Space Sciences	ESS1	12	5	9	26
		ESS2	15	3	17	35
		ESS3	12	5	12	29
	Life Sciences	LS1	9	5	11	25
		LS2	24	2	17	43
		LS3	5	2	6	13
		LS4	16	5	15	36
	Physical Sciences	PS1	10	4	15	29
		PS2	6	6	15	27
		PS3	17	4	10	31
		PS4	8	3	6	17
11	Earth and Space Sciences	ESS1	12	3	12	27
		ESS2	7	3	8	18
		ESS3	11	2	13	26
	Life Sciences	LS1	17	2	21	40
		LS2	16	2	12	30
		LS3	7	2	5	14
		LS4	15	4	13	32

Grade	Science Discipline	Disciplinary Core Idea	ICCR Items	Idaho Items	MOU Items[a]	Total Pool Items[b]
	Physical Sciences	PSC1/2	16	10	14	40
		PSC3	3	2	5	10
		PSP1	8	4	9	21
		PSP2	2	4	5	11
		PSP3	6	4	7	17
Total			**370**	**135**	**423**	**928**

[*]Other MOU state items administered include Connecticut, Hawaii, Rhode Island, Oregon, Utah, West Virginia, and Wyoming. [b]The total count excludes three field-tested items intended for the interim pool.

More information about *p*-values, biserial correlations, and item response theory (IRT) parameters can be found in Volume 1, Annual Technical Report. The details on calibration, equating, and scoring of the ISAT in Science can also be found in Volume 1.

4.4 Paper-Pencil Accommodation Form Construction

Student scores should not depend on the mode of administration or type of test form. Because the ISAT in Science was primarily administered in an online test delivery system in spring 2023, only two students in grade 5 took the paper-pencil form, no students took it in grade 8, and two in grade 11 (all in English) while no student took the Braille forms in the paper mode in any grades. Scores obtained via alternate modes of administration must be established as comparable to scores obtained through online testing. This section outlines the overall test development plans that ensured the comparability of online and paper-pencil tests.

To build paper-pencil forms, content specialists began with the online pool and removed any items that could not be rendered on paper. Next, content specialists constructed fixed forms adhering to the test blueprint. All overall and discipline-level (reporting category) blueprint requirements were met.

5. Simulation Summary Report

This section describes the results of the simulated test administrations used to configure and evaluate the adequacy of the adaptive algorithm, which was used to administer the 2022–2023 ISAT in Science for grades 5, 8, and 11. Simulations were conducted to configure the settings of the algorithm and to evaluate whether individual tests adhered to the test blueprint.

Some important settings included “Select Candidate Set 1” (cset1) and “Select Candidate Set 2” (cset2), which represent subsets of the item pool that were eligible for item selection. Refer to *Appendix 2-L, Adaptive Algorithm Design*, for more details of the current item selection algorithm. In spring 2022, cset1 and cset2 values were set to 10 and 1. Psychometricians reviewed the simulation results and configured settings based on some key diagnostics, including the following:

- **Match-to-Test Blueprint.** This diagnostic determines whether the tests have the correct number of test items overall and the appropriate proportion by content categories at each level of the content hierarchy, as specified in the test blueprints for every science grade.
- **Item Exposure Rate.** This diagnostic evaluates the utility of item pools and identifies overexposed and underexposed items.
- **Precision.** This diagnostic determines whether the size of the standard error of measurement is within the acceptable range and whether estimates of student ability have any possible bias.

These diagnostics are interrelated. For example, if the test pool for a particular content category is limited (i.e., there are only a few test items available), achieving a 100% match to the blueprint for this content level will lead to a high item exposure rate, which means that a large number of students are sharing items. The software system that performs the simulation allows adjustments to the setting parameters in order to attain the best possible balance among these diagnostics. The simulation involves an iterative process that reviews initial results, adjusts these system parameters, runs new simulations, reviews the new results, and repeats the exercise until an optimal balance is achieved. The final setting would then be applied for the operational tests.

5.1 Factors Affecting Simulation Results

There are several factors that may influence simulation results for an adaptive test administration. These factors include the following:

- *The proportional relationship between the pool and the constraints to be met.* Proportionally distributed pools tend to make better use of the pool (i.e., more uniform item exposure) and make it easier to meet blueprint and other constraints. For example, if the specifications call for at least one item cluster per Disciplinary Core Idea (DCI), but the pool has no item cluster for some DCIs, it may be impossible to meet this constraint.
- *The correlational structure between constraints.* It is easier to satisfy a constraint if there are instances of the constraint at all levels of another constraint. For example, if stand-alone items within a discipline are associated only with a specific DCI, it may be difficult to meet both the desired distribution of content and the desired distribution of item type.
- *Whether or not there is a strict maximum on a given constraint.* This means that the requirement must be met exactly in each test administration.

5.2 Results of Simulated Test Administrations: English

This section presents the simulation results for the English online tests, which is the test taken by almost all students (>99%). Simulations were evaluated for all content areas using 5,000 simulated cases per grade.

5.2.1 Summary of Blueprint Match

The simulation results showed no blueprint violations at all content levels for all three grades.

5.2.2 Item Exposure

The simulator output also reports the degree to which the constraints set forth in the blueprints may yield greater exposure of items to students. This is reported by examining the percentage of test administrations in which an item appears. For instance, in a fixed paper-pencil form, 100% of the items appear on 100% of the test administrations because every test taker takes the same form. In an adaptive test or a linear-on-the-fly (LOFT) test with a sufficiently large item pool, it is expected that most of the items would appear on a relatively small percentage of the test administrations.

When this condition holds, it suggests that test administrations between students are more or less unique. Therefore, the item exposure rate was calculated for each item by dividing the total number of test administrations in which an item appears by the total number of tests administered. Then the distribution of the item exposure rate (r) is reported in eight bins. The bins are r = 0% (unused), 0% < r ≤ 1%, 1% < r ≤ 5%, 5% < r ≤ 20%, 20% < r ≤ 40%, 40% < r ≤ 60%, 60% < r ≤ 80%, and 80% < r ≤ 100%. If global item exposure is minimal, it is expected that the largest proportion of items would appear in the bins of 0% < r ≤ 20%, which is an indication that most of the items appear on a very small percentage of the test forms.

Table 24 presents the percentage of items that fell into each exposure bin for all grades. Most test items were administered in 1%–20% of the test administrations. No item had an exposure rate of 0%, and the minimum exposure rate was 0.97% in grade 5. Six items in grade 11 had an exposure rate higher than 40% because of the limitation of the current pool for some content categories.

Table 21. Item Exposure Rates by Grade: Percentage of Items by Exposure Rate, Across All English Online Simulation Sessions

Grade	Total Items	0%	(0,1]%	(1,5]%	(5,20]%	(20,40]%	(40,60]%	(60,80]%	(80,100]%
5	308	0	4.87	48.38	45.78	0.97	0	0	0
8	293	0	22.87	36.86	35.15	5.12	0	0	0
11	266	0	24.44	39.47	25.94	7.89	2.26	0	0

5.2.3 Precision

Each simulated record includes a true score and an ability estimate based on the adaptive test administration. The correlations between the true score and estimated ability for grades 5, 8, and 11 were .948, .953, and .956, respectively. These correlations were fairly high, indicating that the adaptive test administrations reliably estimated student ability.

The mean bias, which is the average of the biases of the estimated abilities across all students, was .016, .001, and –.003 for grades 5, 8, and 11, respectively. In all cases, the mean bias of the estimated abilities was very small, providing further evidence that the true score was adequately recovered in the observed score.

Table 22 shows the mean standard errors of the ability estimate across all simulated test administrations and the standard error at the 5th, 25th, 75th, and 95th percentiles of the ability distribution. For all English tests, the standard error was lowest at the low end of the ability spectrum, indicating a greater precision of measurement of lower performing students. Conversely, the standard error was relatively high for higher ability students, exceeding 0.390 in grade 5.

Table 22. Standard Errors of Ability Estimates, by Grade, Across All English Online Simulation Sessions

Grade	Overall Mean	5th Percentile	25th Percentile	75th Percentile	95th Percentile
5	0.345	0.309	0.328	0.357	0.391

Grade	Overall Mean	5th Percentile	25th Percentile	75th Percentile	95th Percentile
8	0.317	0.286	0.301	0.330	0.362
11	0.309	0.278	0.293	0.317	0.354

5.3 Results of Simulated Test Administrations: Spanish

This section presents the simulation results for the Spanish tests. The Spanish item pool comprised a subset of ICCR items and some MOU items that had Spanish translations available. Table 23 presents the number of items available for the Spanish tests in spring 2023.

Table 23. Spring 2023 Spanish Operational Item Pool

Grade	Item Type	Number of Items
5	Cluster	50
	Stand-Alone	79
8	Cluster	49
	Stand-Alone	74
11	Cluster	66
	Stand-Alone	79
Total		**397**

Simulations were evaluated for all content areas using 1,000 simulated cases per grade.

5.3.1 Summary of Blueprint Match

The simulation results showed no blueprint violations at all content levels for all three grades.

5.3.2 Item Exposure

Table 24 presents the percentage of items that fell into each exposure bin for all grades. Most items were administered in less than 20% of the test administrations. Some items had an exposure rate more than 80% in grade 11 because of the limited Spanish item pool. Only those items were available to satisfy the blueprint constraints.

Table 24. Item Exposure Rates by Grade: Percentage of Items by Exposure Rate, Across All Spanish Simulation Sessions

Grade	Total Items	0%	(0,1]%	(1,5]%	(5,20]%	(20,40]%	(40,60]%	(60,80]%	(80,100]%
5	129	0	0	5.43	77.52	14.73	2.33	0	0
8	123	0	0	30.08	45.53	16.26	8.13	0	0

Grade	Total Items	0%	(0,1]%	(1,5]%	(5,20]%	(20,40]%	(40,60]%	(60,80]%	(80,100]%
11	145	0	17.93	28.28	29.66	16.55	5.52	1.38	0.69

5.3.3 Precision

For the Spanish tests, the correlations between the true score and estimated ability for grades 5, 8, and 11 were .952, .951, and .956, respectively. These correlations were fairly high, indicating that the adaptive test administrations reliably estimated student ability.

The mean bias, which is the average of the biases of the estimated abilities across all students, was –.000, .007, and –.015 for grades 5, 8, and 11, respectively. In all cases, the mean bias of the estimated abilities was very small, providing further evidence that the true score was adequately recovered in the observed score.

Table 25 shows the mean standard errors of the ability estimate across all simulated test administrations and the standard error at the 5th, 25th, 75th, and 95th percentiles of the ability distribution. For all English tests, the standard error was lowest at the low end of the ability spectrum, indicating a greater precision of measurement of lower performing students. Conversely, the standard error was relatively high for higher ability students, exceeding 0.390 in grade 5.

Table 25. Standard Errors of Ability Estimates, by Grade, Across All Spanish Online Simulation Sessions

Grade	Overall Mean	5th Percentile	25th Percentile	75th Percentile	95th Percentile
5	0.343	0.311	0.327	0.352	0.390
8	0.332	0.304	0.318	0.339	0.368
11	0.319	0.285	0.302	0.327	0.368

6. Operational Test Administration Summary Report

This section presents the blueprint match reports and item exposure rates for the spring 2023 operational test administrations.

6.1 Blueprint Match

Table 26 presents the percentages of the spring 2023 tests that aligned with the blueprint requirements. Across all grades, every English and Spanish test administered met the blueprint specifications with a 100% match at all content levels.

Table 26. Spring 2023 Blueprint Match for Test Delivered

Grade	Content Level	MinItems	MaxItems	% of Cases Meeting BP	% of Cases Violating BP			
					1	2	-1	-2
				English				
5	Discipline	6	6	100	-	-	-	-
	Discipline–Cluster	2	2	100	-	-	-	-
	Discipline–Stand-alone	4	4	100	-	-	-	-
	DCI	0	3	100	-	-	-	-
	DCI–Cluster	0	1	100	-	-	-	-
	DCI–Stand-alone	0	2	100	-	-	-	-
	PE	0	1	100	-	-	-	-
8	Discipline	6	6	100	-	-	-	-
	Discipline–Cluster	2	2	100	-	-	-	-
	Discipline–Stand-alone	4	4	100	-	-	-	-
	DCI	0	3	100	-	-	-	-
	DCI–Cluster	0	1	100	-	-	-	-
	DCI–Stand-alone	0	2	100	-	-	-	-
	PE	0	1	100	-	-	-	-
11	Discipline (Physical Science)	7	7	100	-	-	-	-
	Discipline (Physical Science)–Cluster	2	2	100	-	-	-	-
	Discipline (Physical Science)–Stand-alone	5	5	100	-	-	-	-
	Discipline (Life Science/Earth and Space Science)	6	6	100	-	-	-	-
	Discipline (Life Science/Earth and Space Science)–Cluster	2	2	100	-	-	-	-
	Discipline (Life Science/Earth and Space Science)–Stand-alone	4	4	100	-	-	-	-
	DCI	0	3	100	-	-	-	-
	DCI–Cluster	0	1	100	-	-	-	-
	DCI–Stand-alone	0	2	100	-	-	-	-
	PE	0	1	100	-	-	-	-

Grade	Content Level	MinItems	MaxItems	% of Cases Meeting BP	% of Cases Violating BP			
				Spanish				
5	Discipline	6	6	100	-	-	-	-
	Discipline–Cluster	2	2	100	-	-	-	-
	Discipline–Stand-alone	4	4	100	-	-	-	-
	DCI	0	3	100	-	-	-	-
	DCI–Cluster	0	1	100	-	-	-	-
	DCI–Stand-alone	0	2	100	-	-	-	-
	PE	0	1	100	-	-	-	-
8	Discipline	6	6	100	-	-	-	-
	Discipline–Cluster	2	2	100	-	-	-	-
	Discipline–Stand-alone	4	4	100	-	-	-	-
	DCI	0	3	100	-	-	-	-
	DCI–Cluster	0	1	100	-	-	-	-
	DCI–Stand-alone	0	2	100	-	-	-	-
	PE	0	1	100	-	-	-	-
11	Discipline (Physical Science)	7	7	100	-	-	-	-
	Discipline (Physical Science)–Cluster	2	2	100	-	-	-	-
	Discipline (Physical Science)–Stand-alone	5	5	100	-	-	-	-
	Discipline (Life Science/Earth and Space Science)	6	6	100	-	-	-	-
	Discipline (Life Science/Earth and Space Science)–Cluster	2	2	100	-	-	-	-
	Discipline (Life Science/Earth and Space Science)–Stand-alone	4	4	100	-	-	-	-
	DCI	0	3	100	-	-	-	-
	DCI–Cluster	0	1	100	-	-	-	-
	DCI–Stand-alone	0	2	100	-	-	-	-
	PE	0	1	100	-	-	-	-

6.2 ITEM EXPOSURE

Table 27 presents the item exposure rates for the spring 2023 test administration. The exposure rates were very similar to the simulation results described in Section 5.2.2, Item Exposure, most items (95% or more) were administered in 0–60% of the English test administrations. The item exposure rate for field-test items ranged from 6.80%–11.50% for all three grades. For the Spanish tests, more items had high exposure rates compared to the English tests because of a smaller item pool. Also, the operational exposure rates were slightly different from the simulation results because of small population sizes in all three grades. As a result, some items were not exposed at all. In spring 2023, fewer than 100 students took the Spanish test in each grade.

Table 27. Item Exposure Rates by Grade: Percentage of Items by Exposure Rate, Across All Spring 2023 Test Administrations

Grade	Total Items	0%	(0,1]%	(1,5]%	(5,20]%	(20,40]%	(40,60]%	(60,80]%	(80,100]%
English									
5	308	0	6.49	45.45	47.08	0.97	0	0	0
8	293	0	31.06	24.57	37.88	6.48	0	0	0
11	266	0	35.34	28.20	25.94	7.52	2.63	0.38	0
Spanish									
5	129	3.10	0	27.91	51.16	10.85	5.43	1.55	0
8	123	13.82	0	39.02	26.02	8.13	4.07	4.88	4.07
11	145	33.10	0	26.90	22.07	6.21	4.14	4.83	2.76

7. References

Council of Chief State School Officers (CCSSO). (2015). *Science Assessment Item Collaborative (SAIC) Assessment Framework for the Next Generation Science Standards*. Washington, DC: Council of Chief State School Officers. Retrieved from https://ccsso.org/sites/default/files/2017-12/SAICAssessmentFramework_FINAL.pdf.

Mislevy, R. J., & Haertel, G. D. (2006). Implications of evidence-centered design for educational testing. *Educational Measurement: Issues and Practice, 25*(4), 6–20.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Appendix 2-A

Item Writer Training Materials

Exhibit A-1. LABS Guidelines

LABS Guidelines

1. Stereotyping

Testing materials should not present persons stereotyped according to the following characteristics:

- Age
- Disability
- Gender
- Race/Ethnicity
- Sexual orientation

2. Sensitive or Controversial Subjects

Controversial or potentially distressing subjects should be avoided or treated sensitively. For example, a passage discussing the historical importance of a battle is acceptable whereas a graphic description of a battle would not be. Controversial subjects include:

- Death and Disease
- Gambling*
- Politics (Current)
- Race relations
- Religion
- Sexuality
- Superstition
- War

**References to gambling should be avoided in mathematics items related to probability.*

3. Advice

Testing materials should not advocate specific lifestyles or behaviors except in the most general or universally agreed-upon ways. For example, a recipe for a healthful fruit snack is acceptable but a passage recommending a specific diet is not. The following categories of advice should be avoided:

- Religion
- Sexual preference
- Exercise
- Diet

4. Dangerous Activity

Tests should not contain content that portrays people engaged in or explains how to engage in dangerous activities. Examples of dangerous activities include:

- Deep-sea diving
- Stunts
- Parachuting
- Smoking
- Drinking

5. Population Diversity and Ethnocentrism

Testing materials should:

- Reflect the diversity of the testing population
- Use stimulus materials (such as works of literature) produced by members of minority communities
- Use personal names from different ethnic origin communities
- Use pictures of people from different ethnic origin communities
- Avoid *ethnocentrism*, or the attitude that all people should share a particular group's language, beliefs, culture, or religion

6. Differential Familiarity and Elitism

Specialized concepts and terminology extraneous to the core content of test questions should be avoided. This caveat applies to terminology from the fields of:

- Construction
- Finance
- Sports
- Law
- Machinery
- Military topics
- Politics
- Science
- Technology
- Agriculture

7. Language Use

Language should be as inclusive as possible.

- Avoid masculine-coded words like mankind, manmade, and the generic "he"
- Use equal pairs such as husband and wife rather than man and wife

8. Language Accessibility

The grammar and vocabulary should be clear, concise, and appropriate for the intended grade level. The following should be avoided or used with care:

- Passive constructions
- Idioms
- Multiple subordinate clauses
- Pronouns with unclear antecedents
- Multiple-meaning words
- Non-standard grammar
- Dialect
- Jargon

9. Illustrations and Graphics

Illustrations and graphics should embody all of the previously referenced LABS Guidelines.

Exhibit A-2. LABS Checklist

LABS–Checklist

STEREOTYPING CONSIDERATIONS

- ☐ Does the material negatively represent, or stereotype people based on gender or sexual preference?
- ☐ Does the material portray one or more people with disabilities in a negative or stereotypical manner?
- ☐ Does the material portray one or more religious groups as aggressive or violent?
- ☐ Does the material romanticize or demean people based on socioeconomic status?
- ☐ Does the material portray one or more ethnic groups or cultures participating in certain stereotypical activities or occupations?
- ☐ Does the material portray one or more age groups in a negative or stereotypical manner?

SENSITIVE/CONTROVERSIAL MATERIAL CONSIDERATIONS

- ☐ Does the material require a student to take a position that challenges authority?
- ☐ Does the material present war or violence in an overly graphic manner?
- ☐ Does the material present sensitive or highly controversial subjects, such as death, war, abortion, euthanasia, or natural disasters, except where they are needed to meet State Content Standards?
- ☐ Does the material require test takers to disclose values that they would rather hold confidential?
- ☐ Does the material present sexual innuendoes?
- ☐ Does the material trivialize significant or tragic human experiences?
- ☐ Does the material require the parent, teacher, or test taker to support a position that is contrary to their religious beliefs?

ADVICE CONSIDERATIONS

- ☐ Does the material contain advice pertaining to health and well-being about which there is not a universal agreement?

POPULATION DIVERSITY

- ☐ Is the material written by members of diverse groups?
- ☐ Does the material reflect the experiences of diverse groups?
- ☐ Does the material portray people in positive nontraditional roles?
- ☐ Does test material represent the racial and ethnic composition of the testing population?
- ☐ Does the material reflect ethnocentrism?
- ☐ Does the material refer to population subgroups accurately?
- ☐ Does test material reflect diversity through the use of names, cultural references, pictures, and roles?

DIFFERENTIAL FAMILIARITY/ELITISM

- ☐ Does the material contain phrases, concepts, and beliefs that are irrelevant to testing domain and are likely to be more familiar to specific groups that others?
- ☐ Does the material require knowledge of individuals, events, or groups that is not familiar to all groups of students?
- ☐ Does the material suggest that affluence is related to merit or intelligence?
- ☐ Does the material suggest that poverty is related to increased negative behaviors in society?
- ☐ Does the material use language, content, or context that is offensive to people of a particular economic status?
- ☐ Does success with the material assume that the test taker has experience with a certain type of family structure?
- ☐ Does the material favor one socioeconomic group over another?
- ☐ Does the material assume values not shared by all test takers?

LINGUISTIC FEATURES/LANGUAGE ACCESSIBILITY/GRAPHICS

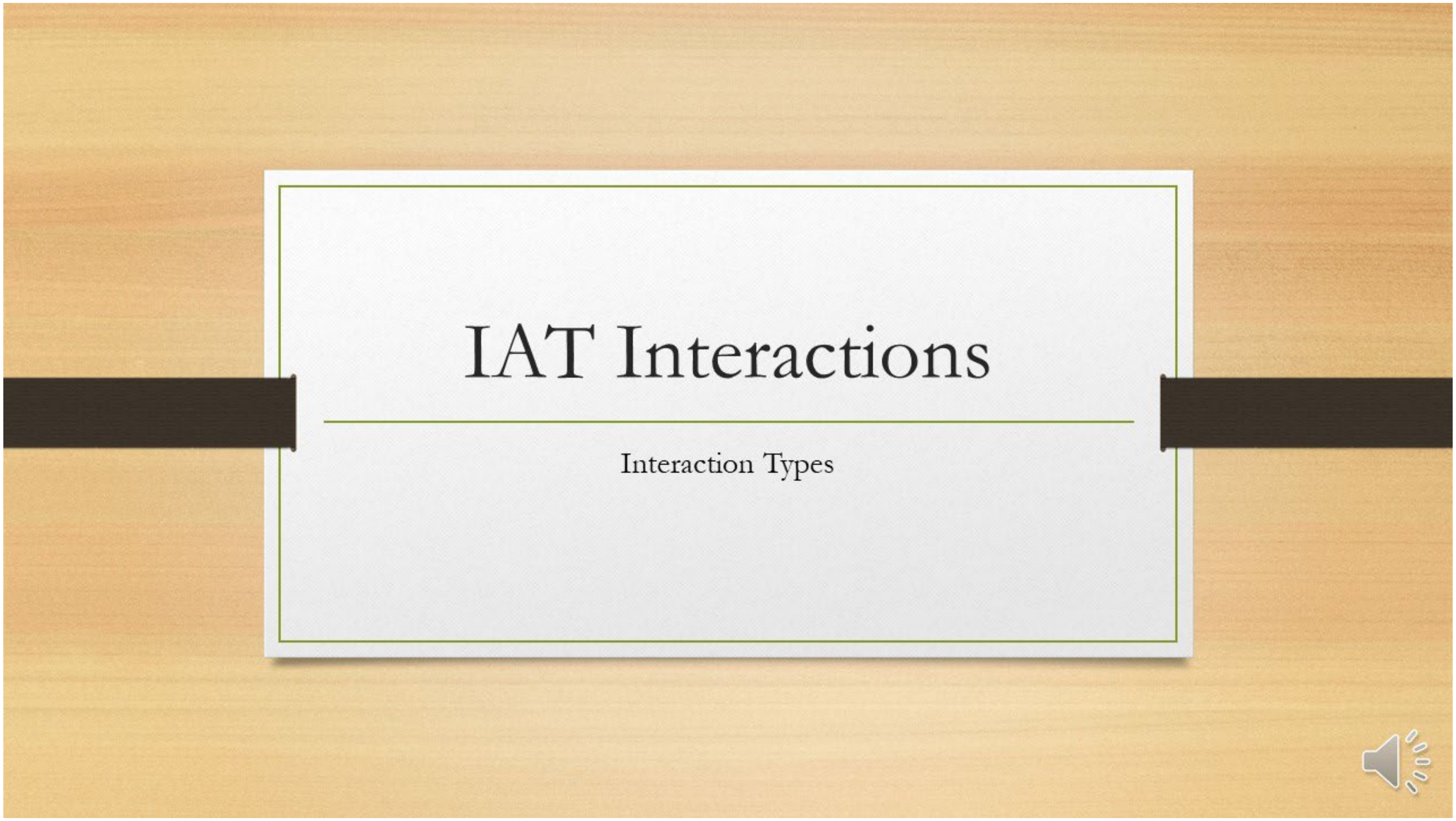
- ☐ Is grammar and vocabulary used in the items clear, concise, and appropriate for the intended grade level?
- ☐ Are passages at a difficulty level that is appropriate for the intended grade level?

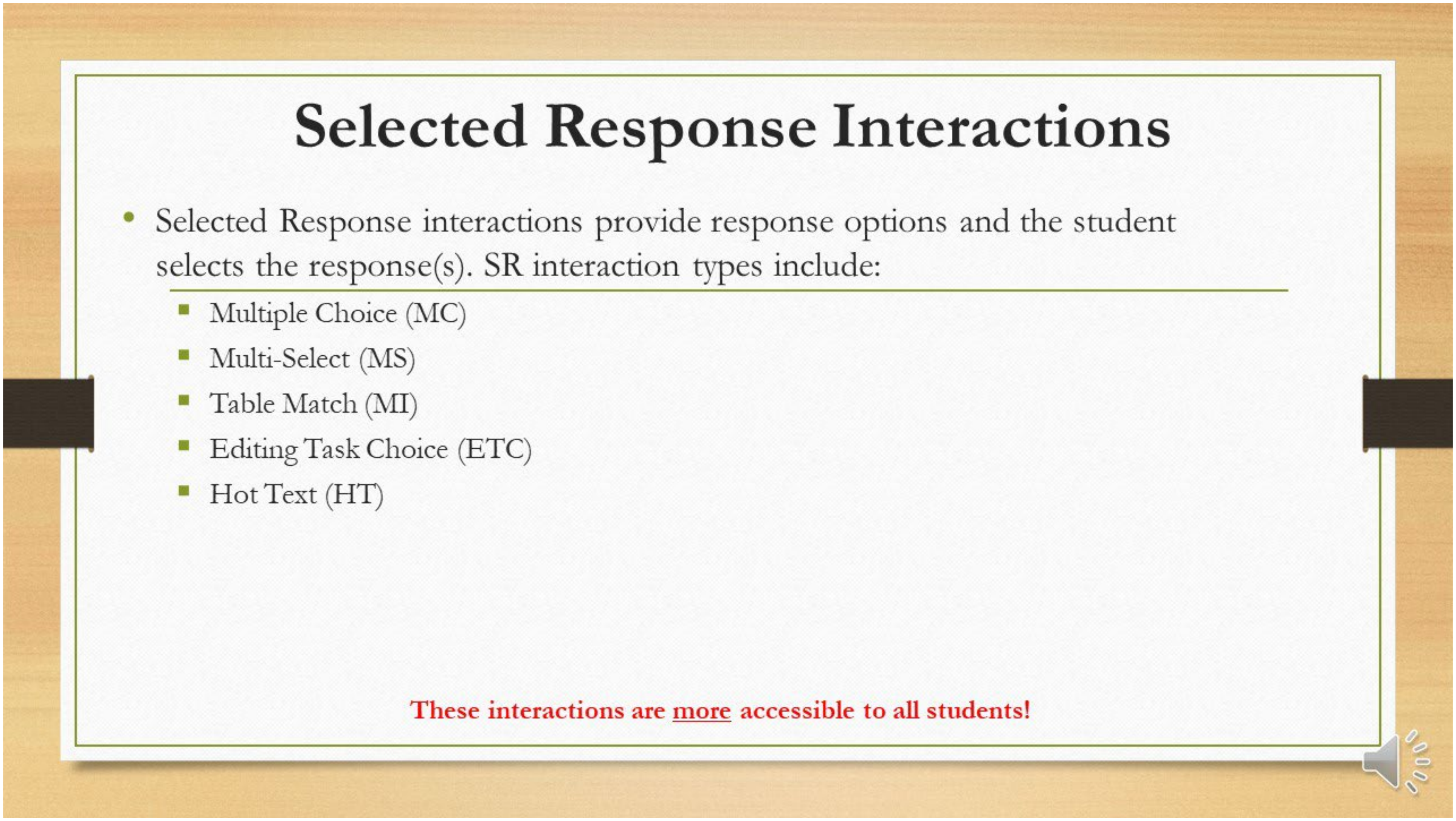
- Do the illustrations and graphics embody all of the previously referenced LABS Guidelines?

OTHER QUESTIONS TO CONSIDER

- Does the material favor one age group over others except in a context where experience or maturation is relevant?
- Does the material use language, content, or context that is not accessible to one or more of the age groups tested?
- Does the material contain language or content that contradicts values held by a certain culture?
- Does the material favor one racial or ethnic group over others?
- Does the material degrade people based on physical appearance or any physical, cognitive, or emotional challenge?
- Does the material focus only on a person's disability rather than portraying the whole person?
- Does the material favor one religion and/or demean others?

Exhibit A-3. An Overview of Interaction Types


IAT Interactions
Interaction Types


Selected Response Interactions
Selected Response interactions provide response options and the student selects the response(s). SR interaction types include:
Multiple Choice (MC)
Multi-Select (MS)
Table Match (MI)
Editing Task Choice (ETC)
Hot Text (HT)
These interactions are more accessible to all students!

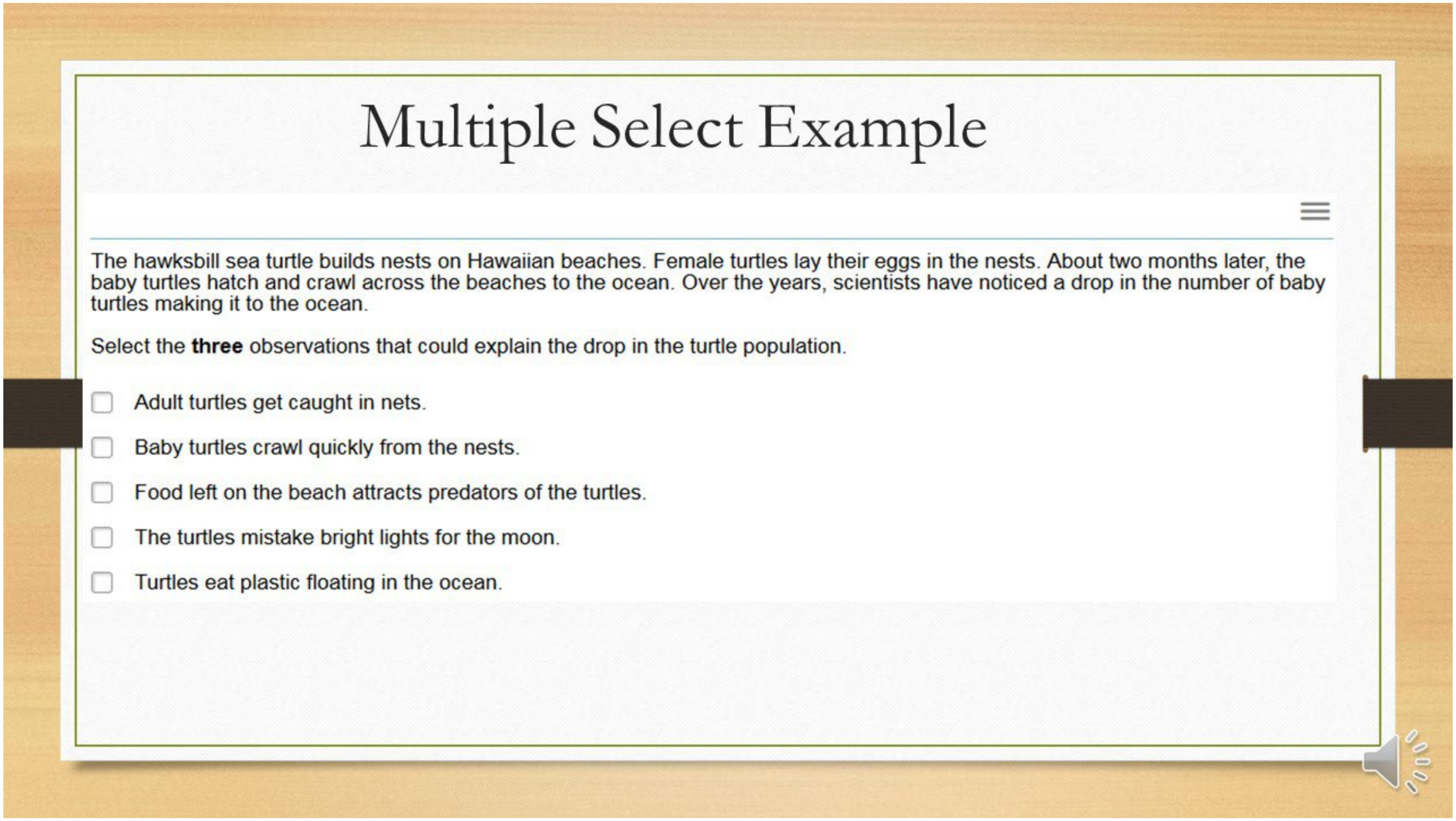
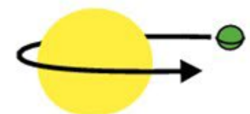

Multiple Select Example
The hawksbill sea turtle builds nests on Hawaiian beaches. Female turtles lay their eggs in the nests. About two months later, the baby turtles hatch and crawl across the beaches to the ocean. Over the years, scientists have noticed a drop in the number of baby turtles making it to the ocean.
Select the **three** observations that could explain the drop in the turtle population.
Adult turtles get caught in nets.
Baby turtles crawl quickly from the nests.
Food left on the beach attracts predators of the turtles.
The turtles mistake bright lights for the moon.
Turtles eat plastic floating in the ocean.

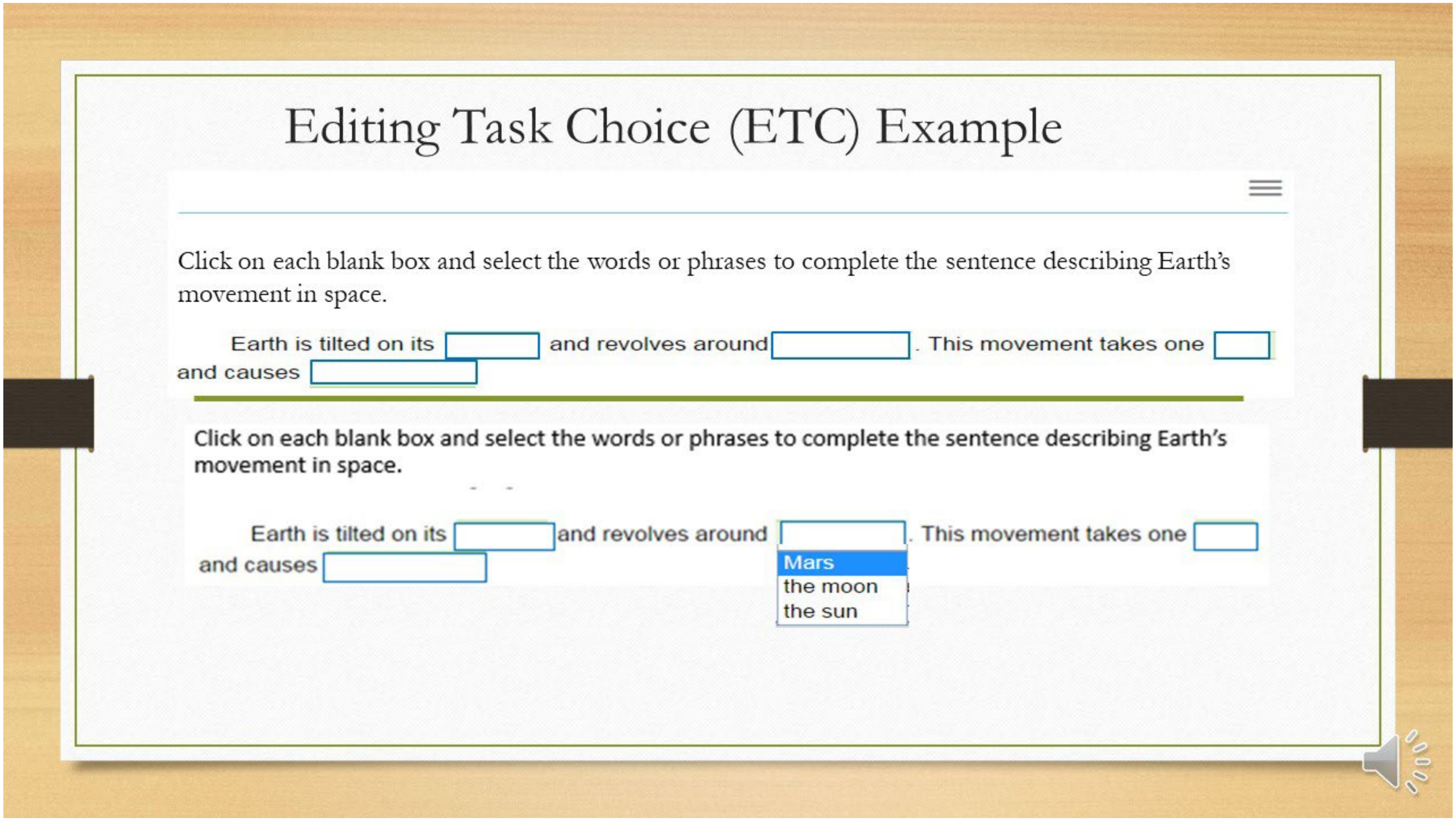
Table Match (MI) Example

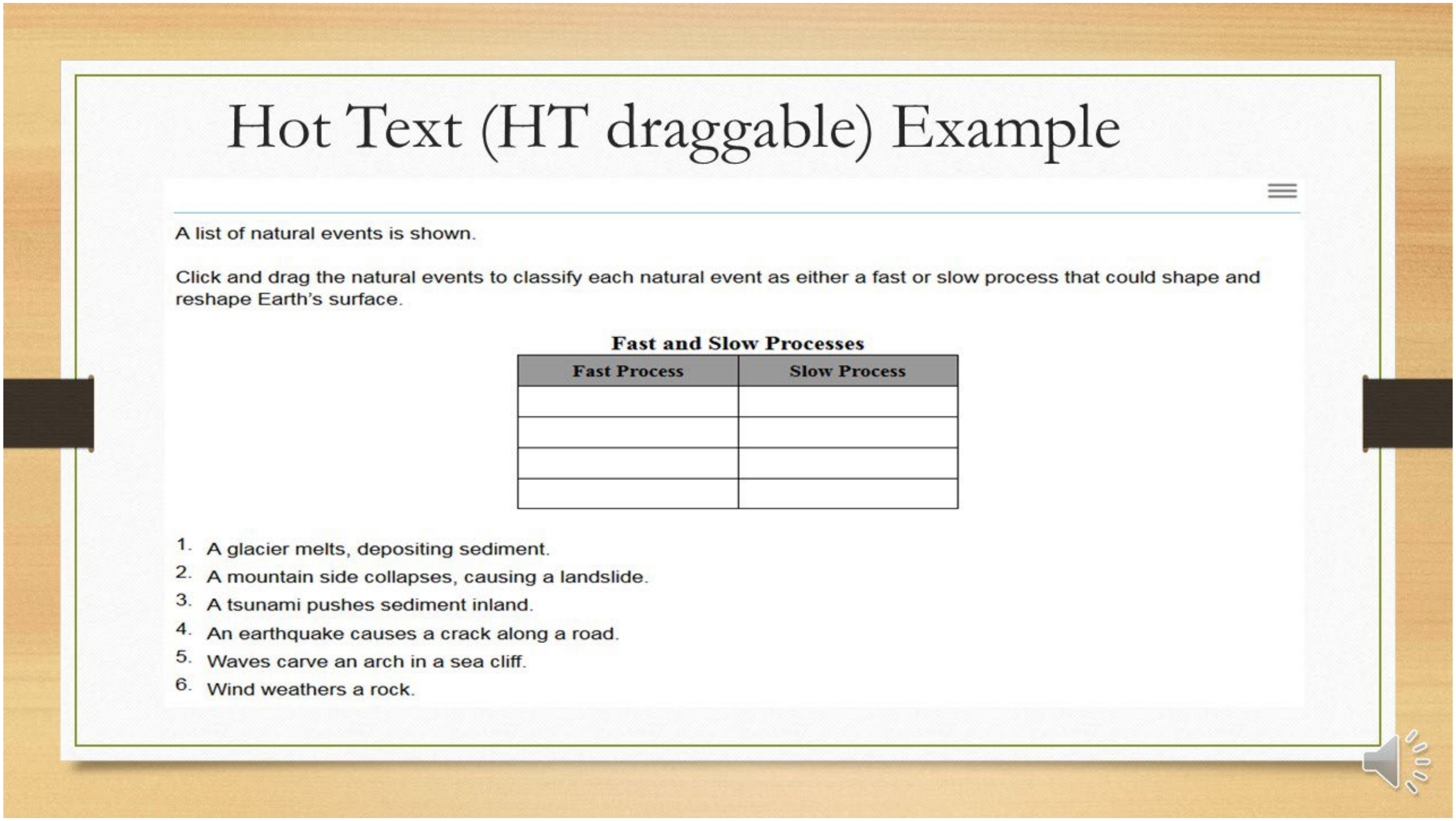
Students use a large yellow ball and a small green ball to model the sun and Earth. They use the balls to explain the cause of day and night, to model the length of a year, and to explain the cause of the seasons.

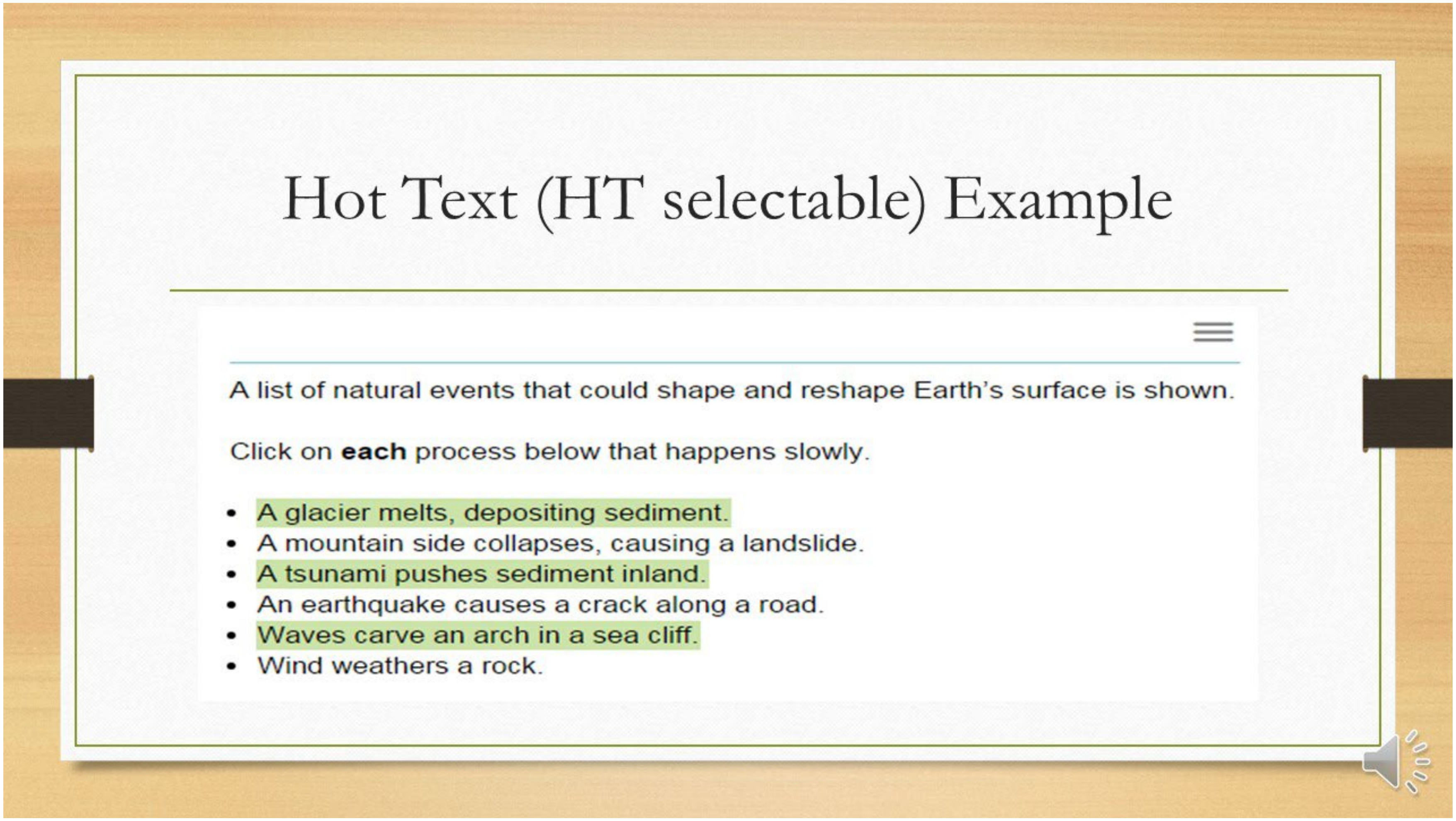
Select **each** box to identify which movements of the balls are needed to explain each phenomenon.

- You can select more than one box for each statement.

	 Large yellow ball is stationary, while small green ball spins.	 Large yellow ball is stationary, while small green ball is tilted.	 Large yellow ball is stationary, while small green ball moves around it.
The cause of day and night	☐	☐	☐
The length of a year	☐	☐	☐
The cause of the seasons	☐	☐	☐


Editing Task Choice (ETC) Example
Click on each blank box and select the words or phrases to complete the sentence describing Earth's movement in space.
Earth is tilted on its and revolves around . This movement takes one and causes
Click on each blank box and select the words or phrases to complete the sentence describing Earth's movement in space.
Earth is tilted on its and revolves around . This movement takes one and causes
Mars
the moon
the sun

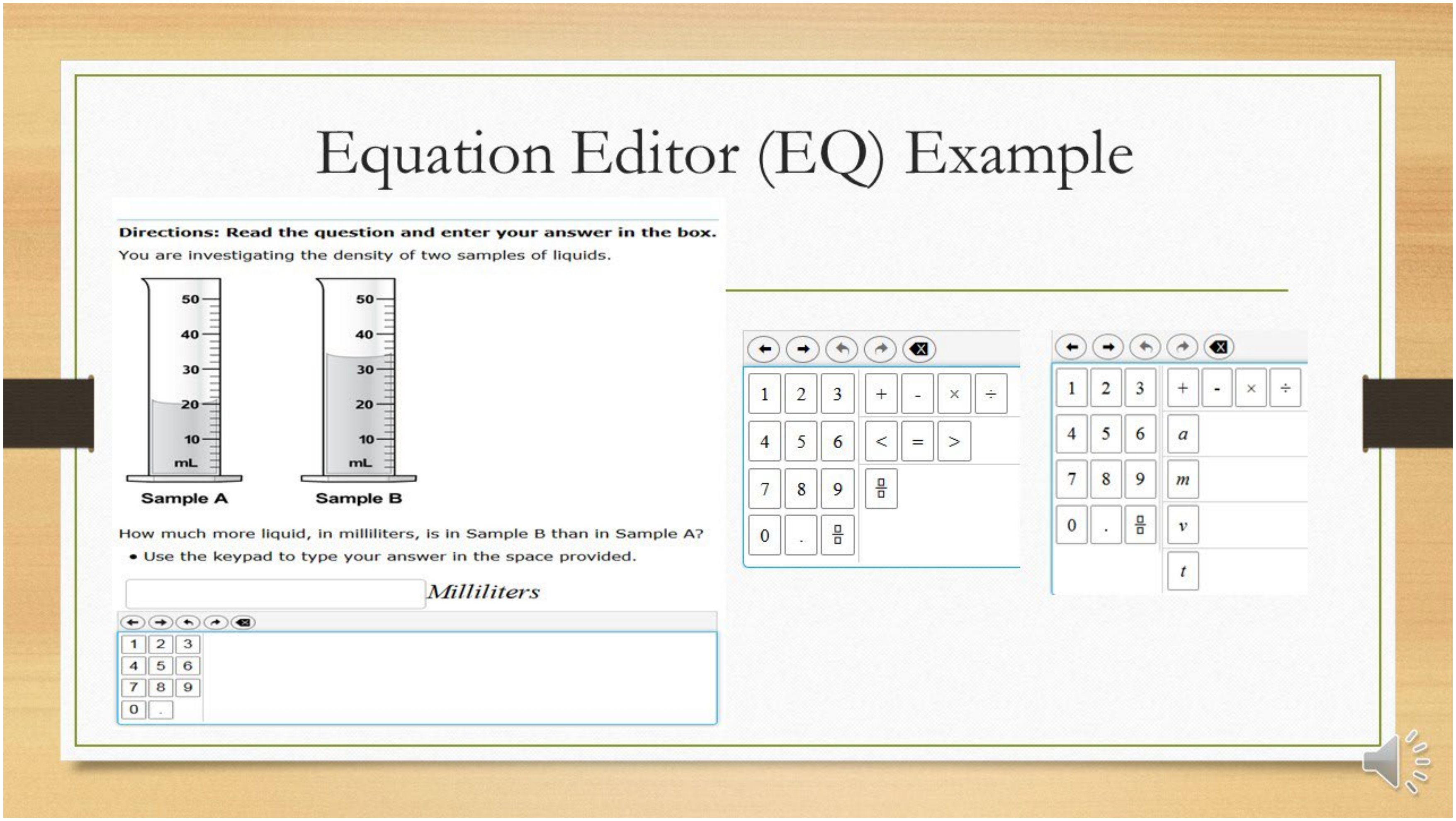

Hot Text (HT draggable) Example
A list of natural events is shown.
Click and drag the natural events to classify each natural event as either a fast or slow process that could shape and reshape Earth's surface.
Fast and Slow Processes
Fast Process
Slow Process
1. A glacier melts, depositing sediment.
2. A mountain side collapses, causing a landslide.
3. A tsunami pushes sediment inland.
4. An earthquake causes a crack along a road.
5. Waves carve an arch in a sea cliff.
6. Wind weathers a rock.


Hot Text (HT selectable) Example
A list of natural events that could shape and reshape Earth's surface is shown.
Click on **each** process below that happens slowly.
• A glacier melts, depositing sediment.
• A mountain side collapses, causing a landslide.
• A tsunami pushes sediment inland.
• An earthquake causes a crack along a road.
• Waves carve an arch in a sea cliff.
• Wind weathers a rock.

Machine Scored Constructed Response Interactions

- Machine Scored Constructed Response interactions require scoring logic or a machine rubric within the interaction. MSCR interaction types include:
  - Equation Editor (EQ)
  - Table Interaction (TI)
  - Grid Interaction (GI)
  - Simulation (Sim)
  - Natural Language (NL)
  - Editing Task (ET)
  - Word Builder (WB)

These interactions are less accessible to all students!


Equation Editor (EQ) Example
Directions: Read the question and enter your answer in the box.
You are investigating the density of two samples of liquids.
Sample A
Sample B
mL
How much more liquid, in milliliters, is in Sample B than in Sample A?
• Use the keypad to type your answer in the space provided.
Milliliters

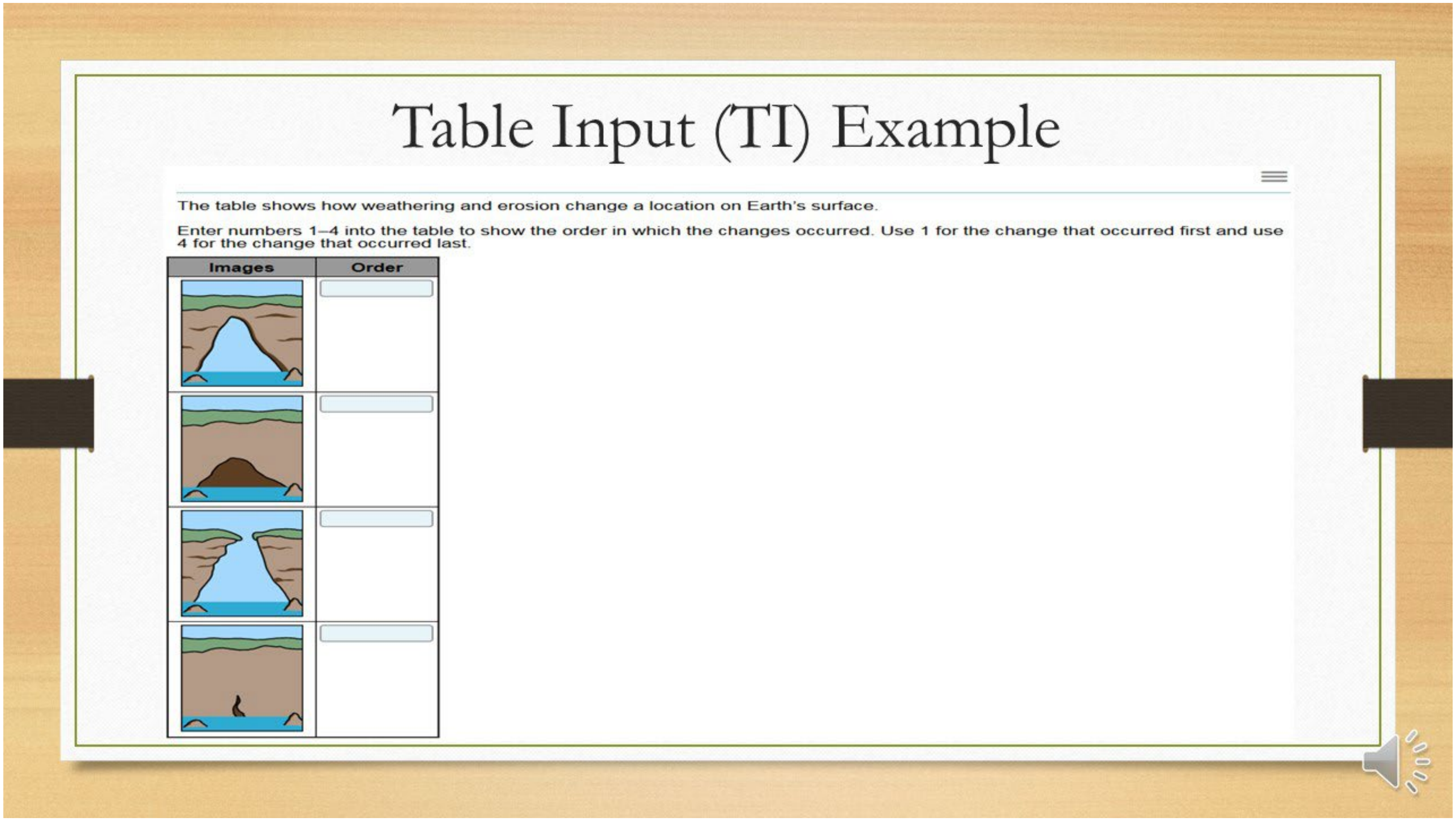
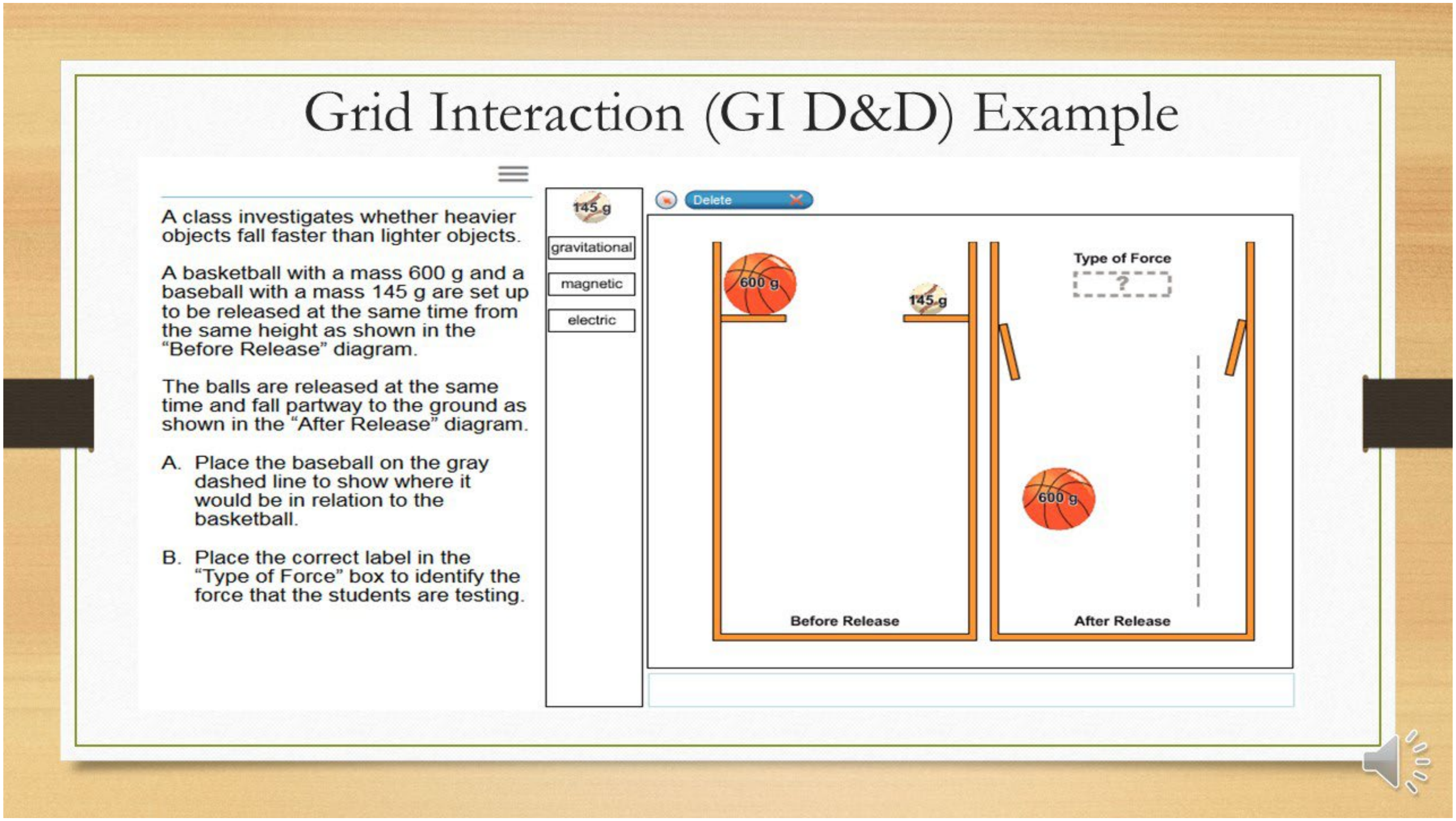
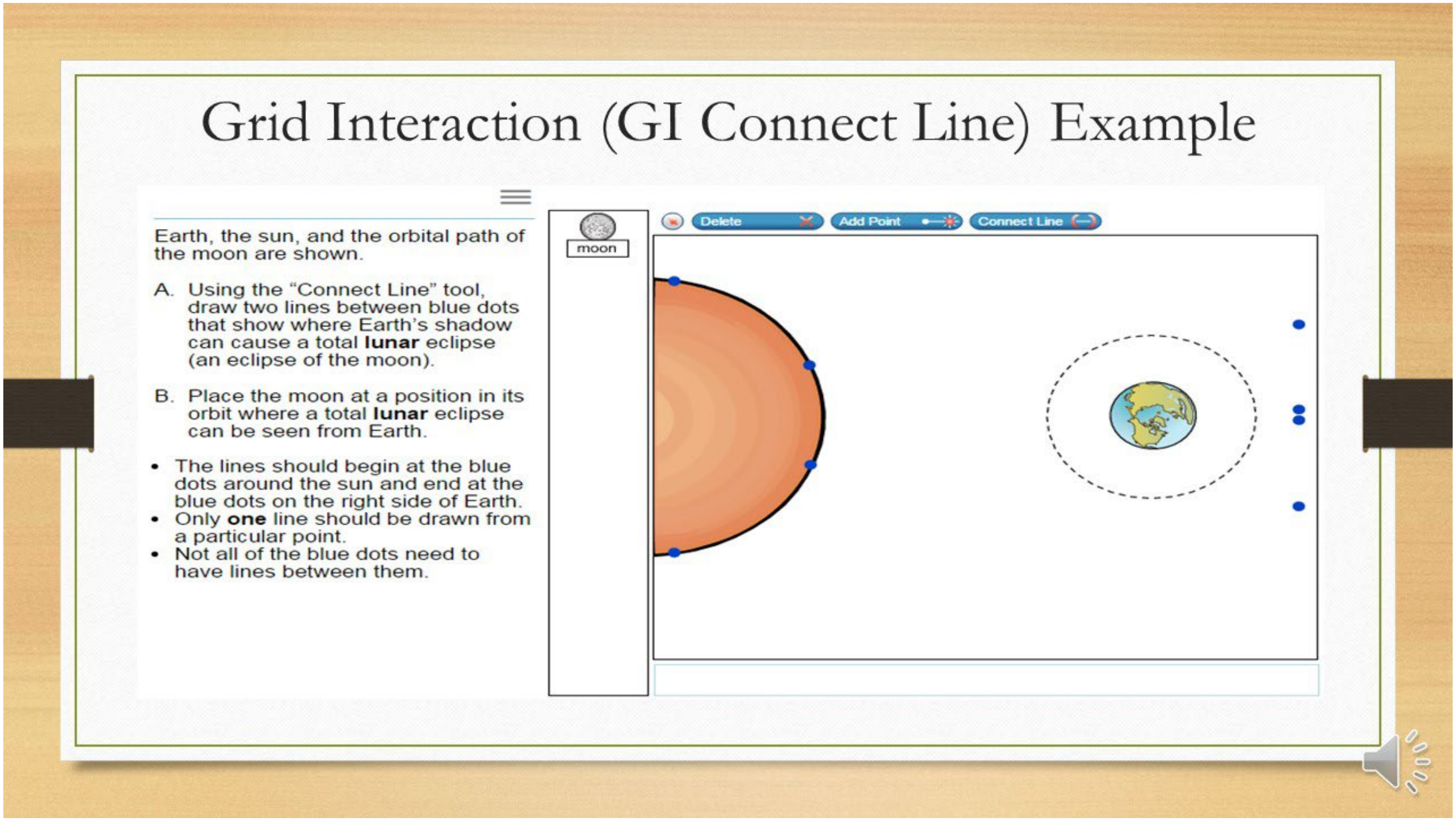
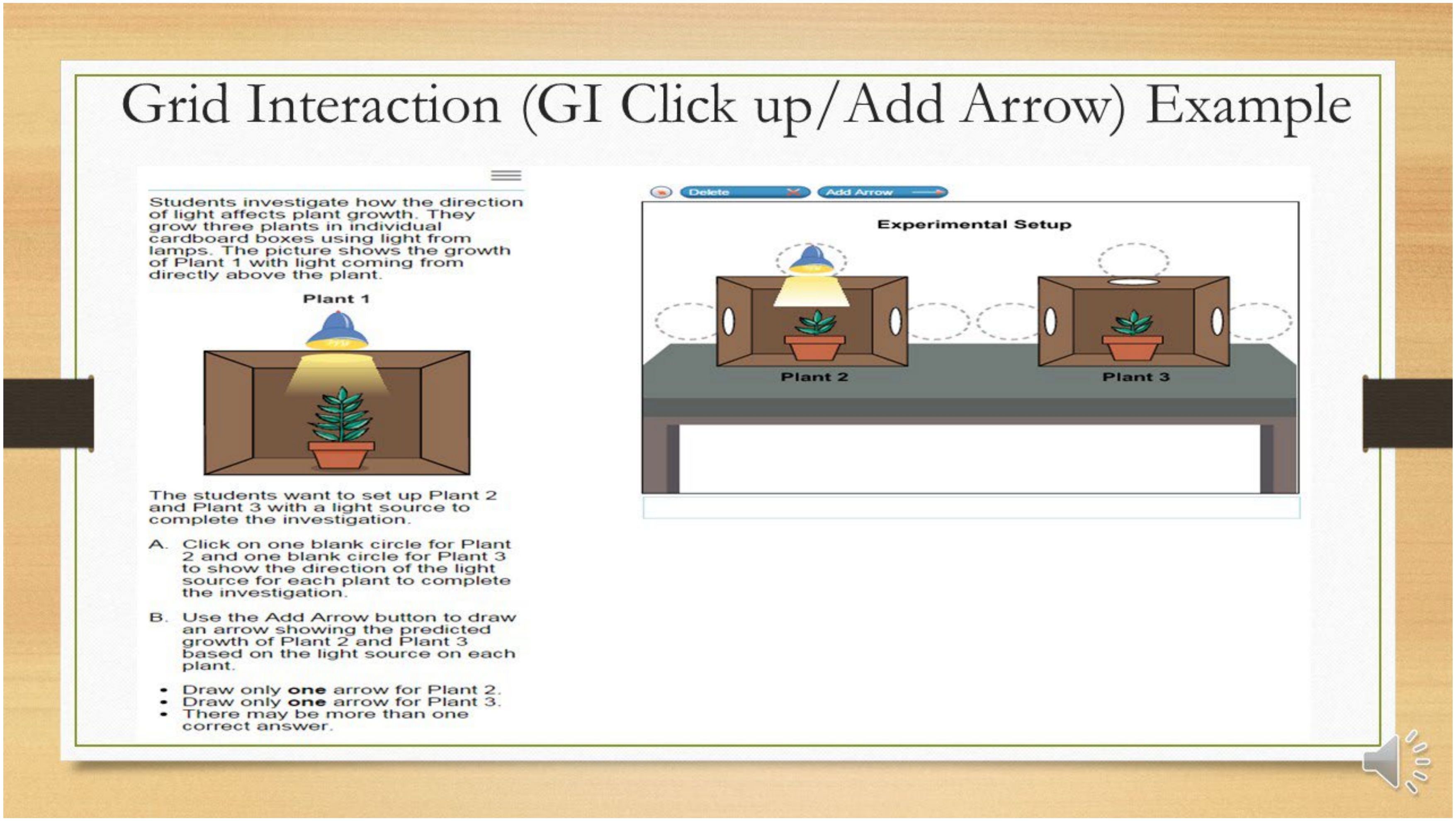
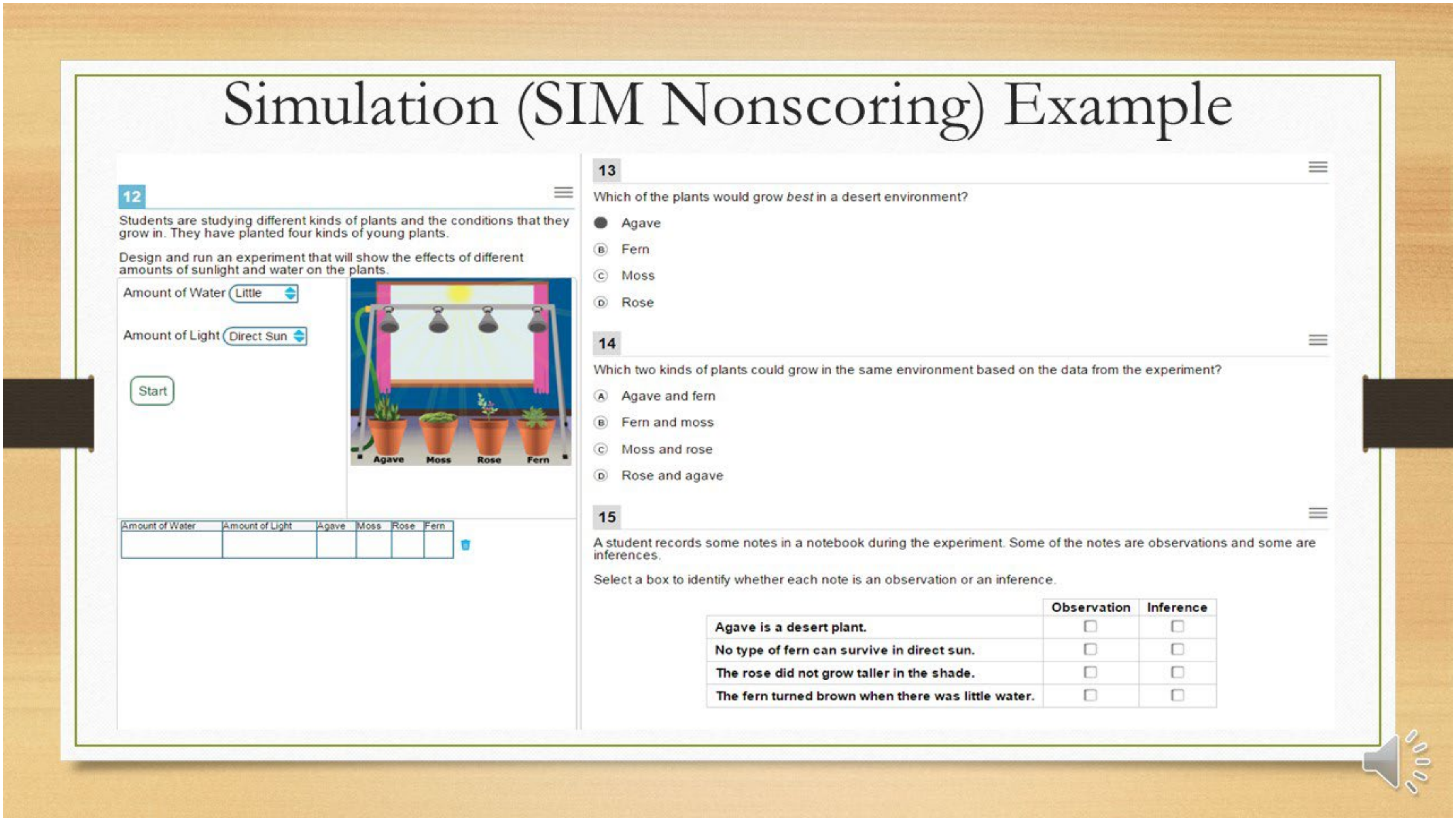


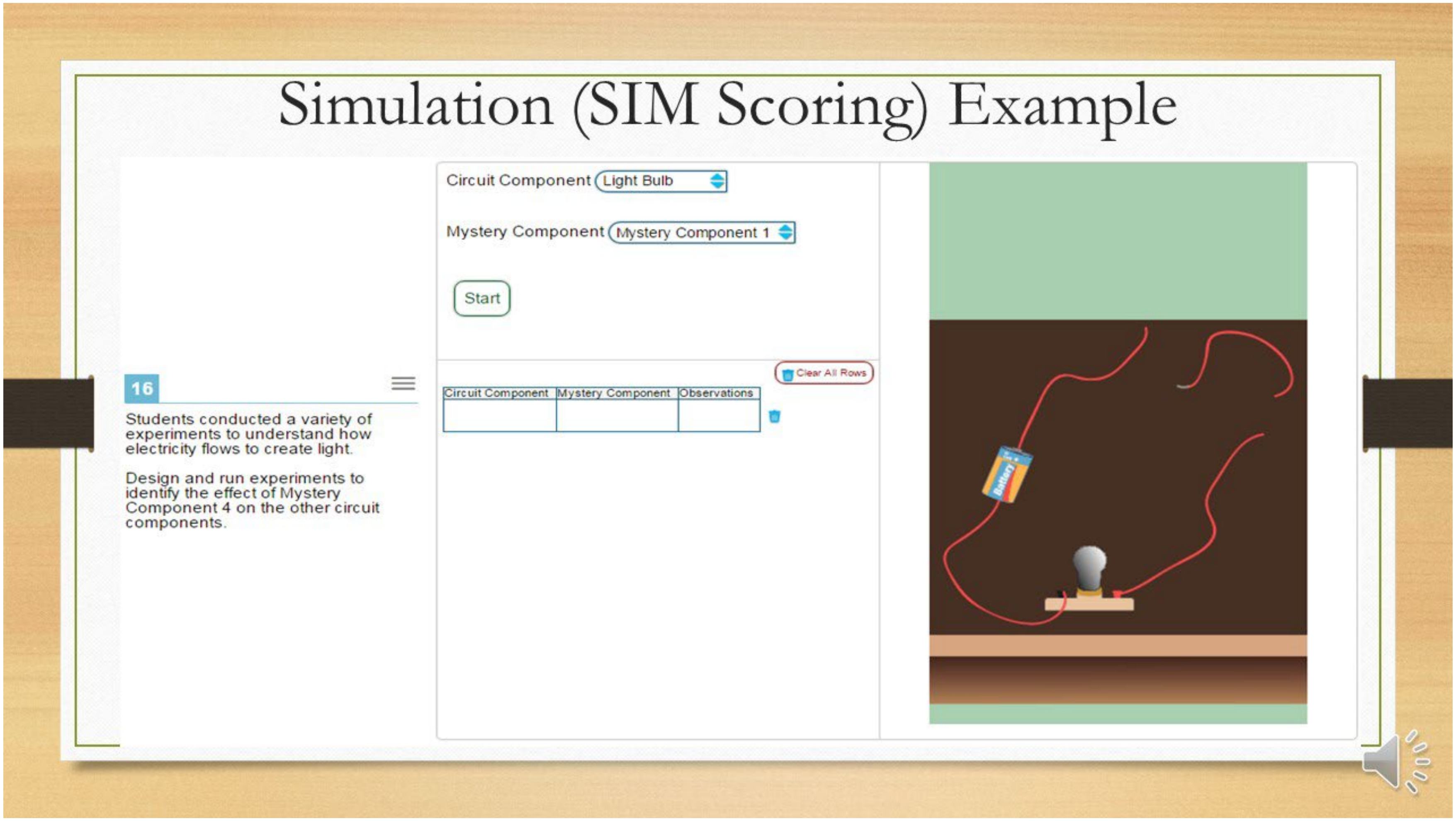
Table Input (TI) Example
The table shows how weathering and erosion change a location on Earth's surface.
Enter numbers 1–4 into the table to show the order in which the changes occurred. Use 1 for the change that occurred first and use 4 for the change that occurred last.
Images
Order

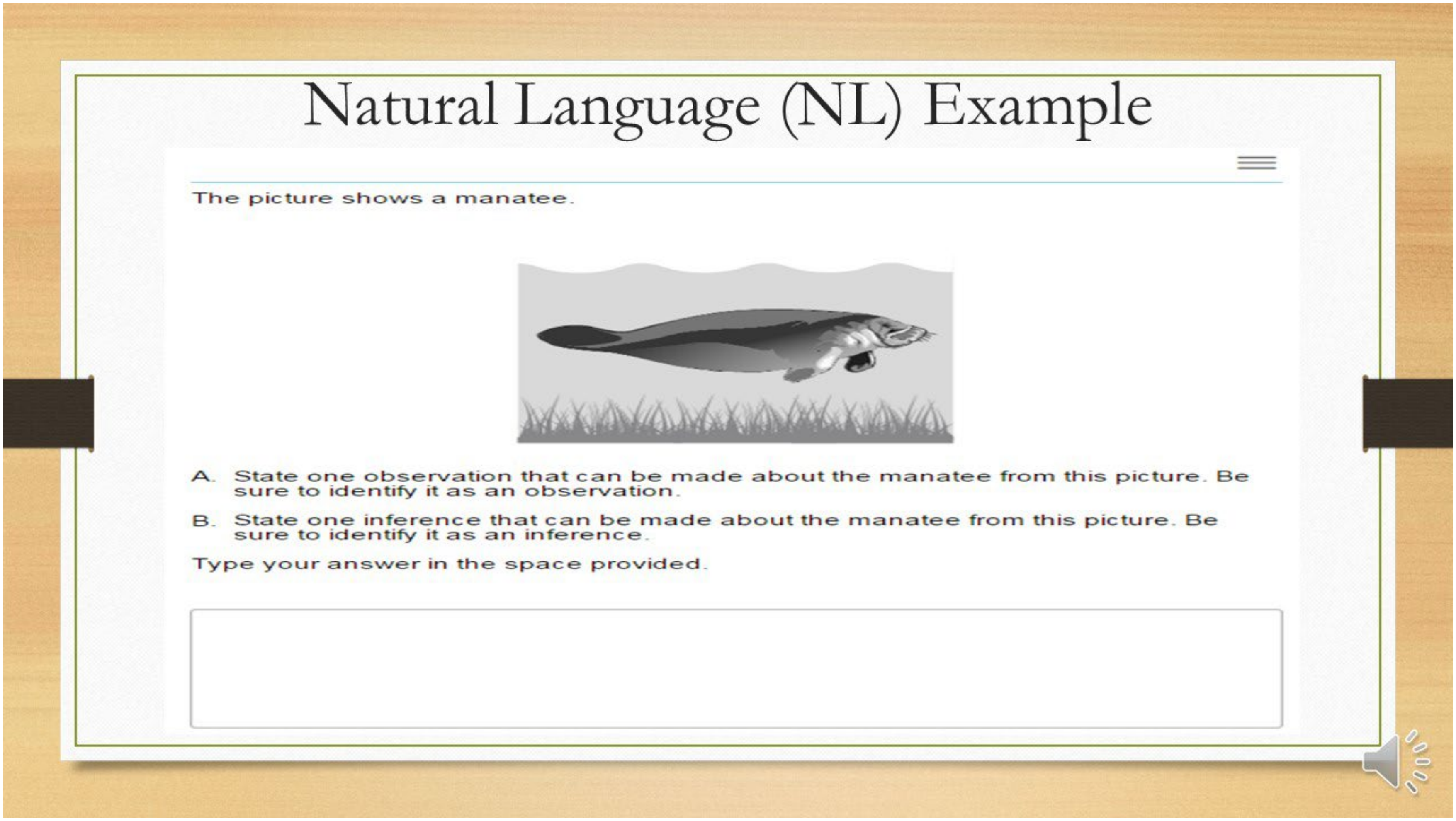

Grid Interaction (GI D&D) Example
A class investigates whether heavier objects fall faster than lighter objects.
A basketball with a mass 600 g and a baseball with a mass 145 g are set up to be released at the same time from the same height as shown in the "Before Release" diagram.
The balls are released at the same time and fall partway to the ground as shown in the "After Release" diagram.
A. Place the baseball on the gray dashed line to show where it would be in relation to the basketball.
B. Place the correct label in the "Type of Force" box to identify the force that the students are testing.
145 g
gravitational
magnetic
electric
Delete
600 g
145 g
Before Release
Type of Force
?
600 g
After Release


Grid Interaction (GI Connect Line) Example
Earth, the sun, and the orbital path of the moon are shown.
A. Using the "Connect Line" tool, draw two lines between blue dots that show where Earth's shadow can cause a total **lunar** eclipse (an eclipse of the moon).
B. Place the moon at a position in its orbit where a total **lunar** eclipse can be seen from Earth.
• The lines should begin at the blue dots around the sun and end at the blue dots on the right side of Earth.
• Only **one** line should be drawn from a particular point.
• Not all of the blue dots need to have lines between them.
moon
Delete
Add Point
Connect Line


Grid Interaction (GI Click up/Add Arrow) Example
Students investigate how the direction of light affects plant growth. They grow three plants in individual cardboard boxes using light from lamps. The picture shows the growth of Plant 1 with light coming from directly above the plant.
Plant 1
The students want to set up Plant 2 and Plant 3 with a light source to complete the investigation.
A. Click on one blank circle for Plant 2 and one blank circle for Plant 3 to show the direction of the light source for each plant to complete the investigation.
B. Use the Add Arrow button to draw an arrow showing the predicted growth of Plant 2 and Plant 3 based on the light source on each plant.
• Draw only one arrow for Plant 2.
• Draw only one arrow for Plant 3.
• There may be more than one correct answer.
Delete
Add Arrow
Experimental Setup
Plant 2
Plant 3


Simulation (SIM Nonscoring) Example
12
Students are studying different kinds of plants and the conditions that they grow in. They have planted four kinds of young plants.
Design and run an experiment that will show the effects of different amounts of sunlight and water on the plants.
Amount of Water
Little
Amount of Light
Direct Sun
Start
Agave
Moss
Rose
Fern
Amount of Water
Amount of Light
Agave
Moss
Rose
Fern
13
Which of the plants would grow best in a desert environment?
Agave
Fern
Moss
Rose
14
Which two kinds of plants could grow in the same environment based on the data from the experiment?
Agave and fern
Fern and moss
Moss and rose
Rose and agave
15
A student records some notes in a notebook during the experiment. Some of the notes are observations and some are inferences.
Select a box to identify whether each note is an observation or an inference.
Observation
Inference
Agave is a desert plant.
No type of fern can survive in direct sun.
The rose did not grow taller in the shade.
The fern turned brown when there was little water.

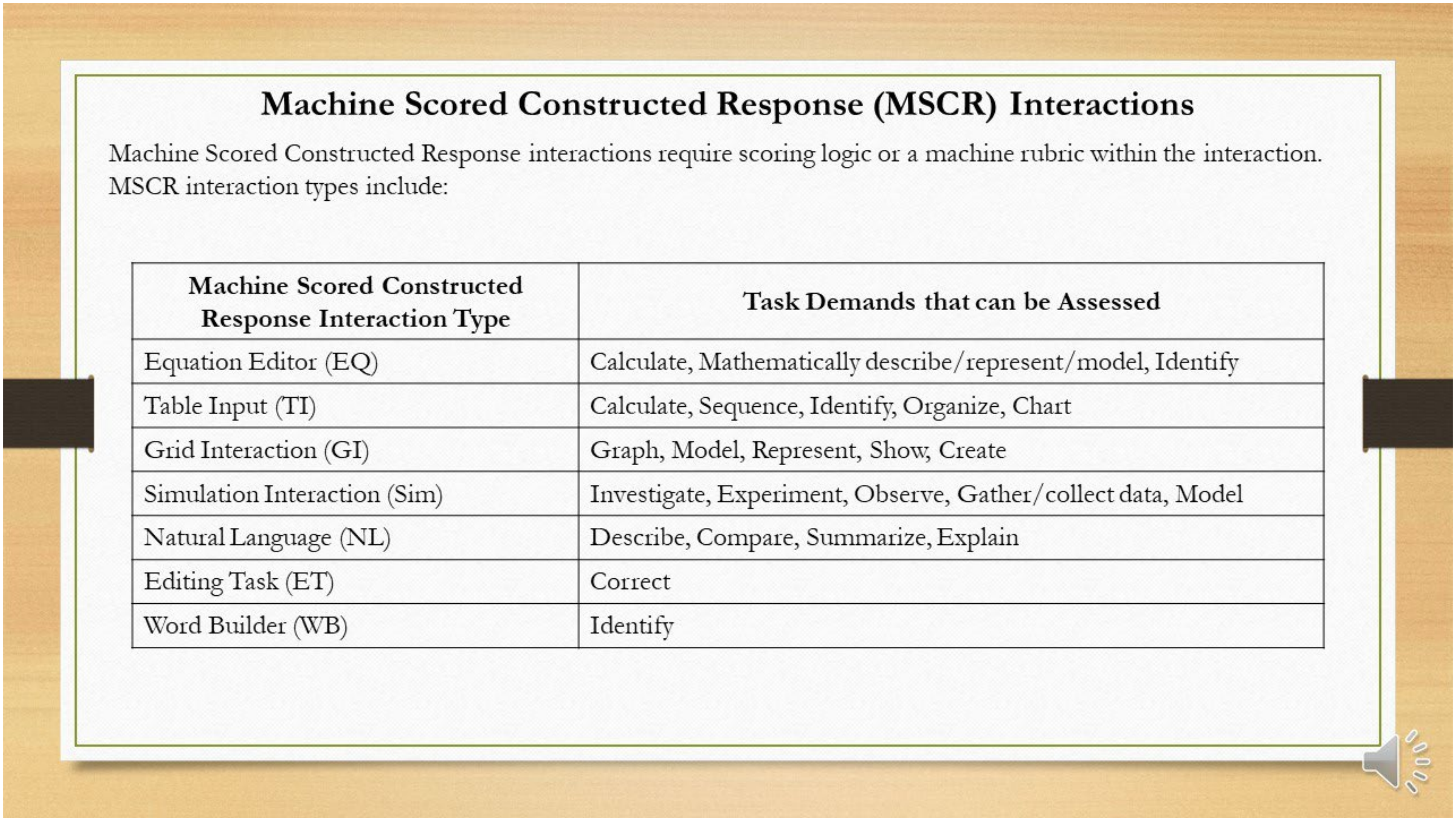

Simulation (SIM Scoring) Example
Circuit Component
Light Bulb
Mystery Component
Mystery Component 1
Start
Clear All Rows
Circuit Component
Mystery Component
Observations
16
Students conducted a variety of experiments to understand how electricity flows to create light.
Design and run experiments to identify the effect of Mystery Component 4 on the other circuit components.


Natural Language (NL) Example
The picture shows a manatee.
A. State one observation that can be made about the manatee from this picture. Be sure to identify it as an observation.
B. State one inference that can be made about the manatee from this picture. Be sure to identify it as an inference.
Type your answer in the space provided.

Selected Response (SR) Interactions

Selected Response interactions provide response options and the student selects the response(s).

SR Interaction Type	Task Demands that can be Assessed
Multiple Choice (MC)	Identify, Choose, Select, Label
Multi Select (MS)	Identify, Choose, Select, Label
Table Match (MI)	Classify, Categorize, Organize, Rank, Sort, Sequence
Editing Task Choice (ETC)	Classify, Categorize, Organize, Sort, Sequence, Compare, Label, Construct an explanation/argument, Describe, Summarize, Complete
Hot Text Selectable (HT)	Highlight, Identify, Select, Choose



Machine Scored Constructed Response (MSCR) Interactions

Machine Scored Constructed Response interactions require scoring logic or a machine rubric within the interaction. MSCR interaction types include:

Machine Scored Constructed Response Interaction Type	Task Demands that can be Assessed
Equation Editor (EQ)	Calculate, Mathematically describe/represent/model, Identify
Table Input (TI)	Calculate, Sequence, Identify, Organize, Chart
Grid Interaction (GI)	Graph, Model, Represent, Show, Create
Simulation Interaction (Sim)	Investigate, Experiment, Observe, Gather/collect data, Model
Natural Language (NL)	Describe, Compare, Summarize, Explain
Editing Task (ET)	Correct
Word Builder (WB)	Identify

Appendix 2-B

Item Specifications – Grade 3 – High School

Introduction

This document presents *cluster specifications* for use with the Next Generation Science Standards (NGSS). These standards are based on the Framework for K-12 Science Education. The present document is not intended to replace the standards, but rather to present guidelines for the development of items and item clusters used to measure those standards.

The remainder of this section provides a very brief introduction to the standards and the framework, an overview of the design and intent of the item clusters, and a description of the cluster specifications that follow. The bulk of the document is composed of cluster specifications, organized by grade and standard.

Background on the framework and standards

The Framework for K-12 Science Education are organized around three core dimensions of scientific understanding. The standards are derived from these same dimensions:

- Disciplinary Core Ideas: The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.
- Science and Engineering Practices: The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.
- Cross-Cutting Concepts: These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.
- There is substantial overlap between and among the three dimensions. For example, the cross-cutting concepts are echoed in many of the disciplinary core ideas. The core ideas are often closely intertwined with the practices. This overlap reflects the nature of science itself. For example, we often come to understand and communicate causal relationships by employing models to make sense of observations. Even within a dimension, overlap exists. Quantifying characteristics of phenomena is important in developing an understanding of them, so employing computational and mathematical thinking in the construction and use of models is a very common scientific practice, and one of the cross-cutting concepts suggests that scientists often infer causality by observing patterns. In short, the dimensions are not orthogonal.

The framework envisions effective science education as occurring at the intersection of these interwoven dimensions: students learn science by doing science—applying the practices through the lens of the cross-cutting concepts to investigate phenomena that relate to the content of the disciplinary core ideas.

Item clusters

Each item cluster is designed to engage the examinee in a grade-appropriate, meaningful scientific activity aligned to a specific standard.

Each cluster begins with a phenomenon, an observable fact or design problem that engages student interest and can be explained, modeled, investigated, or designed using the knowledge and skill described by the standard in question. What it means to be observable varies across practices. For example, a phenomenon for a performance expectation exercising the a*nalyze data* practice may be observable through regularities in a data set, while standards related to the *development and use of models* might be something that can be watched, seen, felt, smelled, or heard.

What it means to be observable also varies across grade levels. For example, elementary-level phenomena are very concrete and directly observable. At the high school level, an observation of the natural world may be more abstract--for

example, "observing" changes in the chemical composition of cells through the observation of macroscopic results of those changes on organism physiology, or through the measurement of system- or organ-level indications.
Content limits refine the intent of the performance expectations and provide limits on what may be asked of items in the cluster to structure the student activity. The content limits also reflect the disciplinary core ideas learning progressions that are present in the K-12 Framework for Science Education.

The task or goal should be explicitly stated in the stimulus or the first item in the cluster: statements such as "In the questions that follow, you will develop a model that will allow you to identify moons of Jupiter," or "In the questions below, you will complete a model to describe the processes that lead to the steam coming out of the teapot."
Whereas item clusters have been described elsewhere as "scaffolded," they are better described as providing structure to the task. For example, some clusters begin with students summarizing data to discover patterns that may have explanatory value. Depending on the grade level and nature of the standard, items may provide complete table shells or labeled graphs to be drawn, or may require the student to choose what to tabulate or graph. Subsequent items may ask the student to note patterns in the tabulated or graphed data and draw on domain content knowledge to posit explanations for the patterns.
These guidelines for clusters do not appear separately in the specifications. Rather, they apply to all clusters.

Structure of the cluster specifications

The item cluster specifications are designed to guide the work of item writers and the review of item clusters by stakeholders.
Each item cluster has the following elements:

- The text of the performance expectations, including the practice, core idea, and cross-cutting concept.
- Content limits, which refine the intent of the performance expectations and provide limits of what may be asked of examinees. For example, they may identify the specific formulae that students are expected to know or not know.
- Vocabulary, which identifies the relevant technical words that students are expected to know, and related words that they are explicitly not expected to know. The vocabulary included in both sections (Students are Expected to Know and Students Are Not Expected to Know) were developed after the reviews of standards at the current/preceding grades, the original NGSS documentation, and item writer reference documentation including the Children Writers' Word Book and ED Core Vocabularies in Reading, Mathematics, Science and Social Studies. All vocabulary included in the specifications was reviewed and edited by teacher committees during the specification reviews by states. Of course, the latter category should not be considered exhaustive, since the boundaries of relevance are ambiguous, and the list is limited by the imagination of the writers/reviewers.
- Sample phenomena, which provide some examples of the sort of phenomena that would support effective item clusters related to the standard in question. In general, these should be guideposts, and item writers should seek comparable phenomena, rather than drawing on those within the documents. Novelty is valued when applying scientific practices.
- Task demands comprise the heart of the specifications. These statements identify the types of items and activities that item writers should use, and each item written should be clearly linked to one or more of the demands. The verbs in the demands (e.g., *select, identify, illustrate, describe*) provide guidance on the types of interactions that item writers might employ to elicit the student response. We avoid explicitly identifying interaction types or item formats to accommodate future innovations and to avoid discouraging imaginative work by the item writers. All task demands should be aligned to a minimum of one of the three dimensions (DCI, SEP and CCCs) and across task demands within a cluster, all three dimensions must be addressed.

- For each cluster we present, the printed documentation includes the cluster, the task demands represented by each item, and its linkage to the content, practice and cross-cutting concept identified in the performance expectation.

Item cluster specifications follow, organized by domain and standard.

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-PS2-1
Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.</td><td>PS2.A: Forces and Motion
• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)

PS2.B: Types of Interactions
• Objects in contact exert forces on each other.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples could include an unbalanced force on one side of a ball can make it start moving, and balanced forces pushing on a box from both sides will not produce any motion at all.

Content Limits
• Assessment is limited to gravity being addressed as a force that pulls objects down.
• Assessment is limited to one variable at a time: number, size, or direction of forces.
• Assessment does include normal force, but not by name or magnitude.
• Assessment does not include quantitative force size, only qualitative and relative.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Strength, direction, speed, gravity, net, sum, weight (physical).</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Velocity, acceleration, mass, friction, vector, quantitative, relative, scale, weight (mass • gravity), Newtons, normal force.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Example Phenomena for 3-PS2-1:
• Kids of the same size and strength play a game of tug of war. When the same number of kids are on each side, a ribbon tied to the rope does not move. When more kids are on one side, the rope moves in that direction.
• A ball rests on the ground, unmoving. When it is gently kicked, it moves slowly in the direction it was kicked. When it is kicked harder, it moves more quickly in the direction it was kicked.
• A box is sitting in the center of a table. Strings attached to the left and right sides of the box hang over the sides of the table. Identical weights can be attached to the end of these strings.
• A flat track with posts and rubber bands on either ends of the track. The student can pull a car back different distances to gather data.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Assemble, complete, or identify, from a collection including distractors, the essential components of an investigation that studies balanced and unbalanced forces on an object at rest and/or in motion.	
2. Identify the variables in the investigation that are held constant and which are changing, and define important factors in the design including number of trials, methods, and techniques.	
3. Identify the observations that should be collected in an investigation of an object's motion to determine the forces on the object and the causes of those forces.	
4. Observe, collect, and record data from observations of the forces acting on an object at rest and/or in motion after forces of different strengths and/or directions are applied, including both balanced and unbalanced forces.*	
5. Identify from a list, including distractors, the effects of forces on an object's motion and the cause of those forces.	
6. Make predictions about the effects of changes in the motion of an object given specific forces. Predictions can be made by manipulating components of the investigation, completing illustrations, or selecting from lists with distractors.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-PS2-2
Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or to test a design solution.</td><td>PS2.A Forces and Motion
• The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it.</td><td>Patterns
• Patterns of change can be used to make predictions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a seesaw.

Content Limits
• Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.
• <u>Students do not need to know:</u> Newton’s laws of motion, Law of Conservation of Energy</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Speed, distance, height, time, mass, force, gravity, electrical field, static electricity, distribution of charged particles, electrical charge, negatively charged, positively charged, neutrally charged, magnetic field, polarity (magnetic), North pole, South pole, attraction, repulsion, electromagnet.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Frequency, amplitude, displacement, equilibrium position, oscillate, momentum, velocity, vector, elastic collision, inelastic collision, friction, acceleration of gravity, work, power, controlled variable, dependent variable, independent variable, kinetic energy, potential energy</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-PS2-2:
• A boy and a girl play on a swing set. In 10 tries, the girl cannot get the boy to swing higher than the height she released him.
• A ball can be thrown farther when a person launches the ball from a plastic ball thrower rather than from his/her bare hand.
• A marble is rolled down a slide. It takes five seconds for the marble to reach the bottom of the slide. The same marble is rolled down another slide. This time, it takes the marble two seconds to reach the bottom of the slide.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify the output data that should be collected in an investigation of an object’s motion.</td></tr>
<tr><td colspan="4">2. Make and/or record observations about an object’s motion as it repeats a pattern over time.</td></tr>
</table>

3. Generate or construct graphs, tables, assemblages of illustrations and/or labels of data that highlight patterns, trends, or correlations in the pattern of an object's motion. This may include sorting out distractors.*
4. Summarize data to highlight trends, patterns, or correlations in the motion of an object.
5. Use relationships identified in the data to predict/infer the future motion of an object.*
6. Identify patterns or evidence in the data that supports predictions/inferences about an object's future motion.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-PS2-3
Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Ask questions that can be investigated based on patterns such as cause and effect relationships.</td><td>PS2.B: Types of Interactions
• Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified, tested, and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets.
• Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.

Content Limits
• Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity. Limit to strictly qualitative observations.
• Limit content to ask questions about how electric and magnetic objects interact, and the investigation of these phenomena within the scope of the classroom.
• Students should be able to identify the direction of the force, but not the shape of the magnetic or electric field.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Attraction, repulsion, north pole, south pole, positive charge, negative charge, static electricity.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Force fields, test charge, protons, neutrons, electrons, field gradients, insulator, conductor.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Example Phenomena for 3-PS2-3:
• A balloon rubbed against a sweater attracts a whole grain oat O-shaped cereal attached to a string.
• A magnet floats on top of another magnet when aligned correctly.
• A magnet touching the underside of a glass table can move a piece of metal sitting above it on top of the table.
• Two opposite poled magnets suspended by strings in air will levitate.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection, questions that will help clarify the properties that are correlated with the strength or direction of the forces in the phenomenon. In addition to plausible distractors, distractors may also include non-testable ("nonscientific") questions.*	
2. Make and/or record observations about how the size of the forces, both magnetic and electric, depend on different characteristics such as strength/orientation of the magnet, the amount of electric charge, materials, etc.	
3. Identify, describe, or select from a collection, characteristics, properties, features, and/or processes to be manipulated or held constant, while gathering information to answer a well-articulated question about the cause and effect relationships of electric or magnetic interactions.*	
4. Select or describe conclusions relevant to the question posed which are supported by the data, especially inferences about causes and effects, related to static electricity and/or magnetism.	
5. Predict outcomes when properties or proximity of the objects are changed, given the inferred cause and effect relationships, related to static electricity and/or magnetism.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development
TD1 and TD3 **must be used together.

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-PS2-4
Define a simple design problem that can be solved by applying scientific ideas about magnets.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Define a simple problem that can be solved through the development of a new or improved object or tool.</td><td>PS2.B: Types of Interactions
• Electric and Magnetic forces between a pair of objects do not require the objects to be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart, and, for forces between two magnets, on their orientation relative to each other.</td><td></td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.

Content Limits
• Students only need to know the basics about magnets. They do not need to know about the magnetic field and how it is shaped for different objects, etc.
• Students do not need to know how a magnet can magnetize other objects; they just need to know that it does. For example, a paper clip is not magnetic but will be attracted to a magnet. (The student does not need to know anything about magnetic domains.)
• Students do not need to know how electricity and magnetism are coupled (that moving electrons create a magnetic field and that a changing magnetic field creates a current).
• Students do not need to know anything about magnets except that they can repel/attract each other based on their orientation relative to each other.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Magnetic, attraction, repulsion, non-contact force, pole, North Pole, South Pole, bar magnet.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Force fields, field gradients, conductor, orientation, magnetic field, exert, interaction, electromagnetism.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-PS2-4:
• The shower leaks because the curtain is not secured to the bottom of the bathtub.
• Things continually fall out of a handbag because the latch is not secure.
• While working on a project, pencil shavings were dropped on the carpet and the vacuum may not have cleaned them all up.
• Two carts used in experiments keep damaging each other when they collide.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify or assemble from a collection, including distractors, the relevant aspects of the problem that given design solutions, if implemented, will resolve/improve.</td></tr>
</table>

2. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained OR to be used to solve the problem. This may entail sorting relevant from irrelevant information or features.
3. Express or complete a causal chain explaining how the repulsion or attraction of magnets will solve the problem that has been identified. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.
4. Using given data, propose/illustrate/assemble a potential device (prototype) or solution.
5. Describe, identify, and/or select information needed to support an explanation about the proposed solution.

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS1-1
Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop models to describe phenomenon.</td><td>LS1.B: Growth and Development of Organisms
• Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.</td><td>Patterns
• Patterns of change can be used to make predictions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Changes organisms go through during their lifetime form a pattern.

Content Limits
• Assessment of plant life cycles is limited to those of flowering plants.
• Assessment does not include details of human reproduction.
• <u>Students do not need to know:</u> the alternation of generations life cycle, the human reproductive system, mitosis and meiosis.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Adult, growth, parent, pollen, offspring, structure, feature, trait, young, root, stem, leaf/leaves, seed, flower, petal</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Organism, breed, transfer, development, germination, reproductive system, cell, tissue, egg, fertilize, genetic, unicellular, multicellular, specialized cell, cell division, variation, juvenile, metamorphosis, chrysalis, pupa, spores, pistil, stamen, ovary, anther, filament, sepal, receptacle, ovule, stigma, style.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-LS1-1:
• A young moth builds a soft case around it called a cocoon and a young butterfly builds a hard case called a chrysalis.
• A young ladybug looks very different from an adult ladybug.
• Plants and animals both form eggs.
• A pea planted in the ground grows into a new pea plant.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select the components needed to model the phenomenon. Components might include stages of life cycles such as birth, growth, reproduction, and death.</td></tr>
<tr><td colspan="4">2. Assemble or complete an illustration or flow chart that is capable of representing the patterns in life cycles of different types of organisms.</td></tr>
<tr><td colspan="4">3. Manipulate the components of a model to demonstrate the changes, properties, processes and/or events that act to result in a phenomenon.</td></tr>
<tr><td colspan="4">4. Make predictions about the effects of changes in life cycles on organisms. Predictions can be made by manipulating model components, completing illustrations, or selecting from a list with distractors.</td></tr>
</table>

5. Given models or diagrams of life cycles, identify relevant components such as birth, growth, reproduction, and death, and how the life cycles are different in each scenario.
6. Identify missing components, relationships, or other limitations of the model of a life cycle.
7. Describe, select, or identify the relationships among components of a model that describe the patterns of life cycles among different organisms.

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS2-1
Construct an argument that some animals form groups that help members survive.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an argument with evidence, data, and/or a model.</td><td>LS2.D: Social Interactions and Group Behavior
• Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Focus is on how being part of a group helps animals obtain food, defend themselves, and cope with changes, and does not cover how group behavior evolved as a result of a survival advantage.

Content Limits
• Assessment does not include the evolution of group behavior.
• <u>Students do not need to know</u>: social hierarchy in animal groups (pecking order, dominance, submissive, altruism).</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Environment, prey, predator, characteristic, habitat, species, herd, inherit, trait, diet, mate, parent</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Organism, social, relative, predation, hereditary, harmful, beneficial, variation, probability, adaptation, decrease, increase, behavioral, variation, ecosystem, pecking order, dominance/submissive behavior, hierarchy, migrate, defend.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-LS2-1:
• In Yellowstone National Park, a wolf preys on a much larger bison.
• In the Willamette Valley, a colony of beavers builds a dam.
• A colony of ants protects its nests.
• A male honey bee returns to a hive each day.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify patterns or evidence in the data that support inferences and/or determine relationships about the effect of group membership on survival of an animal.</td></tr>
<tr><td colspan="4">2. Understand and generate simple bar graphs or tables that document patterns, trends, or relationships between group membership and survival.</td></tr>
<tr><td colspan="4">3. Sort observations/evidence into those that appear to support or not support an argument.</td></tr>
<tr><td colspan="4">4. Based on the provided data, identify or describe a claim regarding the relationship between survival of an animal and being a member of a group.</td></tr>
<tr><td colspan="4">5. Identify, summarize, select or organize given data or other information to support or refute a claim regarding the relationship between group membership and survival of an animal.*</td></tr>
</table>

6. Using evidence, explain the relationship between group membership and survival.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

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<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS3-1
Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to make sense of phenomena using logical reasoning.</td><td>LS3.A: Inheritance of Traits
• Many characteristics of organisms are inherited from their parents.

LS3.B: Variation of Traits
• Different organisms vary in how they look and function because they have different inherited information</td><td>Patterns
• Similarities and differences in patterns can be used to sort and classify natural phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings.

Content Limits
• Emphasis is on organisms other than humans.
• Assessment does not include genetic mechanisms of inheritance and prediction of traits, including concepts of dominant/recessive traits or sex-linked traits.
• Assessment is limited to non-human examples.
• Graphs and charts can include bar graphs, pictographs, pie charts, tally chart.
• Types of math can include simple fractions, simple addition/subtraction.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Parent, sibling, characteristic, offspring, parent-offspring similarity, feature, inherit, inherited characteristic, reproduce</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Transfer, variation, allele, hereditary information, identical, Punnett square, transmission, gene, genetic, genetic variation, dominant trait, recessive trait.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation the phenomena are sets of data. Those are the observed facts that students will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed.

Example Phenomena for 3-LS3-1:
• Two corn plants in a garden reproduce. In the next generation, the offspring vary in height. (Augmentation: We will provide a data table displaying each member of the subsequent generation and the relevant trait possessed.)
• Over a four-year period, the offspring of two tall blueberry plants always grow taller than the offspring of two nearby short blueberry plants. (Augmentation: We will provide a data table of the number of offspring of each plant height over a four-year period, correlated with the parent plants.)</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Organize or summarize data to highlight trends, patterns, or correlations between the traits of offspring and those of their parents and/or siblings.*
2. Generate graphs or tables that document patterns, trends, or correlations in inheritance of traits.*
3. Identify patterns or evidence in the data that support inferences about inheritance of traits from parents to offspring.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS3-2
Use evidence to support the explanation that traits can be influenced by the environment.</td></tr>
<tr><td>Dimensions</td><td>Constructing explanations and designing solutions
• Use evidence (e.g., observations, patterns) to support an explanation.</td><td>LS3.A: Inheritance of Traits
• Other characteristics result from individuals’ interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment.

LS3.B: Variation of Traits
• The environment also affects the traits that an organism develops.</td><td>Cause and Effect
• Cause-and-effect relationships are routinely identified and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of the environment affecting a trait could include normally tall plants that are grown with insufficient water and are stunted; and, a pet dog that is given too much food and little exercise and becomes overweight.

Content Limits
• Assessment should focus on physical traits.
• Content should not include human traits.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Offspring, feature, inherit, diet, survival, flood, drought, habitat, reproduce</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Organism, variation, version, harmful, beneficial, increase, decrease, trend</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-LS3-2:
• The arctic fox is white in winter but turns brown in the summer.
• Flamingoes are born gray, but some become very pink as they grow.
• Trees growing on the edge of cliffs are often bent.
• A goldfish in a pond grows larger than one in a fish bowl.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe or select the relationships, interactions, or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Express or complete a causal chain explaining that traits can be influenced by the environment. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.</td></tr>
<tr><td colspan="4">3. Identify evidence supporting the inference of causation that is expressed in a causal chain.</td></tr>
</table>

4. Use an explanation to predict changes in the trait of an organism given a change in environmental factors.
5. Describe, identify, and/or select information needed to support an explanation of environmental influence on traits.

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<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS4-1
Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to make sense of phenomena using logical reasoning, mathematics, and/or computation.</td><td>LS4.A: Evidence of Common Ancestry and Diversity
• Some kinds of plants and animals that once lived on Earth are no longer found anywhere.
• Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments.</td><td>Scale, Proportion, and Quantity
• Observable phenomena exist from very short to very long periods.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of data could include type, size, and distributions of fossil organisms.
• Examples of fossils and environments could include marine fossils found on dry land, tropical plant fossils found in Arctic areas, and fossils of extinct organisms.
• Focus is on the fossils and environment in which the organisms lived, not how the fossils got to where they are today.
• Data can be represented in tables and/or various graphic displays.
• Data collected by different groups can be compared and contrasted to discuss similarities and differences in their findings.

Content Limits
• Assessment does not include identification of specific fossils or present plants and animals.
• Assessment is limited to major fossil types and relative ages.
• Graphs and charts can include bar graphs, pictographs, pie charts, and tally charts.
• Types of math can include simple addition/subtraction.
• Standard units that can be used to measure and describe physical quantities such as weight, time, temperature, and volume.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Exist, existence, ecosystem, characteristic, habitat, species, volcanic eruption, climate, extinct, extinction, predator, time period, earthquake, erosion, weathering.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Chronological order, fossil record, radioactive dating, descent, ancestry, evolution, evolutionary, genetic, relative, rock layer.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation, the phenomena are sets of data. Those are the observed facts that students will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed.

Some example phenomena for 3-LS4-1:
• Fossil trees are found in sedimentary rocks in Antarctica.
• The Redwall Limestone in the Grand Canyon contains many different fossils including corals, clams, octopi, and fish.</td></tr>
</table>

	• Whale fossils have been found in rocks in the Andes Mountains. • Fossils of corals and snails are found in Iowa.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize or summarize data to highlight trends, patterns, or correlations between plant and animal fossils and the environments in which they lived.
2. Generate graphs or tables that document patterns, trends, or correlations in the fossil record.
3. Identify evidence in the data that supports inferences about plant and animal fossils and the environments in which they lived.

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS4-2
Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Use evidence (e.g., observations, patterns) to construct an explanation.</td><td>LS4.B: Natural Selection
• Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of cause and effect relationships could be: plants that have larger thorns than other plants may be less likely to be eaten, and animals that have better camouflage coloration than other animals may be more likely to survive and therefore more likely to leave offspring.

Content Limits
• Differences between individuals helping or hurting chances of survival and reproduction should be included.
• Data sets can include not only common trends but also outliers and anomalous data points.
• Analysis of data should be limited to patterns and trends.
• Students are not expected to evaluate the extent at which the sample is representative of a population.
• <u>Students do not need to know</u>: Mechanisms or patterns of inheritance, detailed life cycles.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Variation, advantage, reproduce, relationship, mating, breeding, behavior, plumage, pollination, camouflage.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Natural and artificial selection, evolution, genetics, adaptation,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-LS4-2:
• The same species of walking stick in California has two different color variations. The green walking sticks are found on bushes with thick green leaves, whereas the striped walking sticks are found on bushes with needle-like leaves.
• In a given population, there are more male [X Bird] with larger, brighter feathers in the population than males with smaller, muted feathers.
• Acacia trees that are browsed upon by X animal grow longer thorns at X height. Acacia trees that are browsed upon by Y animal grow longer thorns at Y height. Acacia trees that are not browsed upon at all do not grow longer thorns.
• Io moths use eyespots on their inner wings to frighten predators away. Larger eyespots are more effective.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Articulate, describe, illustrate, or select the variations of characteristics to be explained. This may entail sorting relevant from irrelevant information or features.
2. Identify evidence supporting the conclusion that the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.
3. Describe, identify, and/or select information needed to support an explanation that a characteristic provides advantages in surviving and reproducing.
4. Select or identify a prediction about survival or reproduction rates given a change in a characteristic. The prediction should follow from an explanation or causal relationship supported in earlier items.
5. Identify additional evidence that would help clarify, support, or contradict a hypothesized relationship between characteristics of individuals and their chances of survival and reproductive rates.
6. Express or complete a causal chain that explains how different characteristics among individuals of the same species provide advantages in survival and reproduction. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause and effect chains.*
7. Use evidence to construct an explanation for differences in survival and/or reproduction given a difference in traits between individuals of the same species.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS4-3
Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an argument with evidence.</td><td>LS4.C: Adaptation
• For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of evidence could include needs and characteristics of the organisms and habitats involved. The organisms and their habitat make up a system in which the parts depend on each other.

Content Limits
• While students are not expected to know the definitions to vocabulary terms such as extinction, climate, and mimic, they are expected to know the general concepts behind these terms.
• <u>Students do not need to know:</u> mechanisms of natural selection and evolution of species.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Habitat, health, species, population, region, resource, behavior, growth, petal, thorn, structure, characteristics, mate, trait.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Organism, threaten, impact, terrestrial, climate change, response, body plan, external, function, internal, invertebrate, adaptation, beneficial change, detrimental change, species diversity, gene, variation, artificial selection, natural selection.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-LS4-3:
• Desert plants are able to survive where there is little to no rain.
• Black bears survive the harsh winter months of their forest habitats by going into a deep sleep.
• The artic fox is better able to survive in colder climates than the red fox.
• Emperor penguins have special traits which help them survive in Antarctica.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
<tr><td colspan="4">1. Organize or summarize data to highlight trends, patterns, and/or determine relationships between the traits of an organism and survival in its environment.</td></tr>
<tr><td colspan="4">2. Understand and generate simple bar graphs or tables that document patterns, trends, or relationships between traits of an organism and its survival in a particular environment.</td></tr>
<tr><td colspan="4">3. Identify patterns or evidence in the data that supports inferences about characteristics of an organism and those of its environment.</td></tr>
</table>

4. Based on the provided data, identify or describe a claim regarding the relationship between the characteristics of an organism and survival in a particular environment.*
5. Evaluate the evidence to sort relevant from irrelevant information regarding survival of an organism in a particular environment.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-LS4-4
Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.</td><td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (secondary)

LS4.D: Biodiversity and Humans
• Populations live in a variety of habitats and change in those habitats affects the organisms living there.</td><td>Systems and System Models
• A system can be described in terms of its components and their interactions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.

Content Limits
• Assessment is limited to a single environmental change.
• Assessment does not include the greenhouse effect or climate change.
• <u>Students do not need to know</u>: greenhouse effect, ultraviolet (UV) radiation, nuclear disasters.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Population, organism, community, habitat, resource, reproduce, shelter, temperature, matter, predator, prey, flood, frost, tide</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Ecosystem, biotic, abiotic, food web, producer, consumer, decomposer, photosynthesis, pollinate, adapt, energy flow, biosphere, sustain, predation, mutualism, carrying capacity, volcano, earthquake, drought, arid, blight.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-LS4-4
• To help ornamental bushes grow, no other plants should grow in their immediate vicinity.
• Before stocking a lake with fish, the lake pollution needs to be reduced.
• A late frost threatens the orange groves in Georgia.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes involved when the types of plants and/or animals change as a result of environmental changes. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Identify a problem that results when the types of plants and/or animals change as a result of environmental changes.</td></tr>
</table>

3. Express or complete a causal chain explaining a solution to problem that results when the types of plants and/or animals change as a result of environmental changes. The causal chain should include the ecosystem before the environmental change, the environmental change, the problem to plants and animals resulting from the environmental change, the solution to the problem, and the effect(s) of the solution on the ecosystem. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.*
4. Identify and/or evaluate evidence related to a solution to a problem caused when the types of plants and/or animals change as a result of environmental changes. The evidence may support or refute the solution, or students may identify missing evidence.
5. Evaluate a solution to a problem that results when the types of plants and/or animals change as a result of environmental changes, including how the solution may affect plants, animals, and/or other aspects of the ecosystem.*
6. Identify information or data needed to support or refute a claim regarding a problem resulting from an environmental change affecting the native plants and animals.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-ESS2-1
Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships.</td><td>ESS2.D: Weather and Climate
• Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next.</td><td>Patterns
• Patterns of change can be used to make predictions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of data could include average temperature, precipitation, and wind direction.

Content Limits
• Assessment of graphical displays is limited to pictographs and bar graphs.
• Assessment does not include climate change.
• <u>Students do not need to know:</u> probabilities or how to calculate them, fronts and pressure systems, the movements of weather systems.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Season, weather, temperature, precipitation, patterns, average, latitude, longitude</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Probability, anthropogenic change</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-ESS2-1:
• Vienna, Austria, records more sunny days in the summer than in the winter. Data: Average sunshine hours by month for the city, given as a table or graph.
• People in Florida can often go outside without jackets during the winter. Data: Months and Temperatures for Florida, given as table or graph.
• Visitors to the desert in Death Valley, California, were surprised to be rained on. Data: Months and Precipitation Averages for the region given as table or graph.
• Flags in California's San Joaquin Valley are seen blowing to the SE for most of the year, but are seen blowing to the NW in winter months. Data: Monthly average wind direction (and maybe speed) for the region, given as a table or graphic with wind direction arrows.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in weather patterns.*</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in weather patterns. This may include sorting out distractors.*</td></tr>
</table>

3. Use relationships and patterns identified in the data to predict weather.
4. Identify patterns or evidence in the data that support conclusions about weather. **

*denotes those task demands which are deemed appropriate for use in stand-alone item development.
**TD4 can be used for stand-alone item development if paired with TD2.

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-ESS2-2
Obtain and combine information to describe climates in different regions of the world.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Obtain and combine information from books and other reliable media to explain phenomena.</td><td>ESS2.D: Weather and Climate
• Climate describes a range of an area’s typical weather conditions and the extent to which those conditions vary over years.</td><td>Patterns
• Patterns of change can be used to make predictions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• <u>Students do not need to know:</u> complex interactions that cause weather patterns and climate, the role of the water cycle in weather.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Prediction, precipitation, glacier, ocean, region, climate, vegetation, latitude, longitude, drought, temperature, freeze, atmosphere.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Average, high pressure, low pressure, air mass, altitude, humidity, radiation, water cycle.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 3-ESS2-2:
• Anchorage, Alaska has cool summers and very cold winters with a lot of snowfall.
• It often snows in Colorado in July, but it does not often snow in Kansas in July.
• On the western side of the Cascade Mountains of Oregon, it rains frequently, but on the eastern side, it does not.
• The temperature in London, England does not get very hot in summer or very cold in winter.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange data (including labels and symbols) regarding the climates in different regions to highlight/identify trends or patterns, or make comparisons/contrasts between different regions and/or climatically relevant aspects of their geology and/or geography.*</td></tr>
<tr><td colspan="4">2. Generate or construct tables or assemblages of data (including labels and symbols) that document the similarities and differences between climates of different regions (this includes completing incomplete maps).</td></tr>
<tr><td colspan="4">3. Analyze and interpret scientific evidence (including textural and numerical information as well labels and symbols) from multiple sources (e.g., texts, maps, and/or graphs) that help identify patterns in weather in regions of different climate. This includes communicating the analysis or interpretation.*</td></tr>
<tr><td colspan="4">4. Analyze and interpret patterns of information on maps (including textural and numerical information as well labels and symbols) to explain, infer, or predict patterns of weather over time in a region.*</td></tr>
<tr><td colspan="4">5. Based on the information that is obtained and/or combined, identify, assert, describe, or illustrate a claim regarding the relationship between the location of a region and its climate, or the relationship between geological and/or geographical aspects/characteristics of a region and its climate.*</td></tr>
<tr><td colspan="4">6. Use spatial and/or temporal relationships identified in the obtained and/or combined climate data to predict typical weather conditions in a region.</td></tr>
</table>

7. Organize and/or arrange data regarding the climate of a region to highlight/identify trends or relationships between the weather patterns of a region and its geology and/or geography.
8. Analyze and interpret scientific evidence (including textural and numerical information as well labels and symbols) from multiple sources (e.g., texts, maps, and/or graphs) that helps identify patterns in climate based on geography and/or geology. This includes communicating the analysis or interpretation.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">3-ESS3-1
Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.</td><td>ESS3.B: Natural Hazards
• A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts.</td><td>Cause and Effect
• Cause-and-effect relationships are routinely identified, tested, and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Assessment Clarifications
• Examples of design solutions to weather-related hazards could include barriers to prevent flooding, wind resistant roofs, and lighting rods.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Natural process, earthquake, tsunami, tornado, flooding, severe weather, coastal erosion, landslide, avalanche, dams, levees, lightning, lightning rod, forecast, drought.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Fault line, names of clouds, names of storms, magma, types of volcanoes, low pressure, high pressure systems, El Niño, La Niña, jet stream.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation, phenomena should refer to hazard and one or more design solutions.

Some example phenomena for 3-ESS3-1:
• A building with a lightning rod is struck by lightning more often than the surrounding buildings.
• When the water level of the Feather River was high in February 2017, the water never rose higher than the levees around it, and no flooding occurred. When the water level of the Russian River was high in February 2017, the surrounding area flooded.
• A house built near the ocean in Surfside, New Jersey, sits on stilts/posts.
• A basement in a building fitted with a sump pump does not have mold while the basements of other nearby buildings have mold.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify or assemble from a collection, including distractors, the relevant aspects of the hazard that a given design solution resolves/improves.</td></tr>
<tr><td colspan="4">2. Using the given information, select or identify the criteria against which the design solution should be judged.</td></tr>
<tr><td colspan="4">3. Using given information, select or identify constraints that the design solution must meet.</td></tr>
<tr><td colspan="4">4. Identify missing components, relationships, or other limitations of the design solution.</td></tr>
</table>

5. Use an explanation to predict the outcome of a hazard given a change in the design solution.
6. Make a claim about the merit of the design solution that can be defended.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-PS3-1
Use evidence to construct an explanation relating the speed of an object to the energy of that object.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Use evidence (e.g., measurements, observations, patterns) to construct an explanation.</td><td>PS3.A: Definitions of Energy
• The faster a given object is moving, the more energy it possesses.</td><td>Energy and Matter
• Energy can be transferred in various ways and between objects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.
• Students are expected to know that energy can be expressed through sound, heat, light, and motion.
• <u>Students do not need to know:</u> Students do not need to know how to calculate speed, the change in speed (acceleration), or energy. This standard is limited to making strictly qualitative or comparative observations.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Volume, collision, heat transfer, spring (coil), forms of energy (sound, heat, light, motion), conservation of energy, stored energy, energy transfer, gravity.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Potential energy, kinetic energy, thermal energy, acceleration, velocity.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 4-PS3-1:
• One drum can be used to produce loud or quiet percussion sounds.
• A small bouncing basketball sounds louder than a large bouncing basketball.
• Damage caused during a high-speed collision is greater than when speeds are slower.
• A ceramic bowl dropped from a greater height will have a larger debris pattern.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.**</td></tr>
<tr><td colspan="4">2. Express or complete a causal chain explaining that changes in energy and speed are related. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.*</td></tr>
<tr><td colspan="4">3. Identify evidence supporting the inference of causation that is expressed in a causal chain.</td></tr>
<tr><td colspan="4">4. Use an explanation to predict how the speed of an object changes given a change in energy or how the expression of energy will change given a change in speed.</td></tr>
<tr><td colspan="4">5. Describe, identify, and/or select information needed to support an explanation.</td></tr>
</table>

*denotes those task demands which are deemed appropriate for use in stand-alone item development

**TD 1 should only be used if paired with TD2. TD 2 can be used alone.

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Performance Expectation	**4-PS3-2** Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.		
Dimensions	**Planning and Carrying Out Investigations** • Make observations to produce data to serve as the basis for evidence for an explanation of a phenomena or to test a design solution.	**PS3.A: Definitions of Energy** • Energy can be moved from place to place by moving objects — or through sound, light, or electric currents. **PS3.B: Conservation of Energy and Energy Transfer** • Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. • Light also transfers energy from place to place. • Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.	**Energy and Matter** • Energy can be transferred in various ways and between objects.
Clarifications and Content Limits	**Content Limits** • Assessment does not include quantitative measurements of energy. • Identifying how energy is transferred (example: conduction vs. convection) is not part of this PE. • <u>Students do not need to know</u>: Students do not need to know how to do energy calculations. This standard is limited to strictly making observations. Students should know that energy can be given off as heat or light, but not specifics such as convection, thermal radiation, etc.		
Science Vocabulary Students Are Expected to Know	Collision, speed, flow, heat conduction, conversion.		
Science Vocabulary Students Are Not Expected to Know	Kinetic energy, potential energy, radiation, convection, transmission, reflection, decibels, resonance, friction, hertz, electromagnetic radiation, magnitude, motion energy, electric circuit, thermal, conservation of energy.		
Phenomena			
Context/ Phenomena	Some example phenomena for 4-PS3-2: • A light bulb can be powered using the motion of a hamster wheel. • A drinking glass can be broken by a person singing a certain note. • A fan (with blades angled at 45 degrees) will spin when placed safely over burning candles. • Touching a Van der Graaf generator will make your hair stick up.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			

1. Identify the materials/tools needed for an investigation of how energy is transferred from place to place through heat, sound, light, or electric currents.
2. Identify the data that should be collected in an investigation of how energy is transferred from one place to another through heat, sound, light, or electric currents.
3. Make and/or record observations about the transfer of energy from one place to another via heat, sound, light, or electric currents.**
4. Interpret and/or communicate the data from an investigation.**
5. Select, describe, or illustrate a prediction made by applying the findings from an investigation.

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD3 and TD4 <u>must be</u> used together.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-PS3-3
Ask questions and predict outcomes about the changes in energy that occur when objects collide.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause-and-effect relationships.</td><td>PS3.A: Definitions of Energy
• Energy can be moved from place to place by moving objects or through sound, light, or electric currents.

PS3.B: Conservation of Energy and Energy Transfer
• Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.

PS3.C: Relationship Between Energy and Forces
• When objects collide, the contact forces transfer energy so as to change the objects’ motions.</td><td>Energy and Matter
• Energy can be transferred in various ways and between objects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.

Content Limits
• Assessment does not include quantitative measurements of energy.
• <u>Students do not need to know</u>: names of energy types, how to calculate energy or forces</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Electric currents, speed, flow, conversion, motion, magnets, magnetism, heat conduction.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Kinetic energy, potential energy, friction, force fields, vector, magnitude, elastic, inelastic.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 4-PS3-3:
• A large wave crashes into the cliffs of Étretat and some rocks are knocked loose. A small wave then crashes into the cliffs.
• A person hits a nail with a hammer and the nail is driven into a board. The person swings the hammer again, but misses the nail.
• A person walks down a hallway. The sound of their shoes on the floor can be heard many feet away. The person then runs down the hallway.
• A bowler rolls a ball down a lane. It slams into the pins and knocks several of them down. After the pins are reset, the bowler rolls the ball down the lane again. The ball misses and knocks down no pins.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Select or identify from a collection, including distractors, questions that will help clarify the properties that are correlated with the changes in energy that occur in the phenomenon. In addition to distractors that are plausible responses, distractors may include non-testable (“nonscientific”) questions.
2. Identify, describe, or select from a collection, including distractors, characteristics to be manipulated or held constant while gathering information to answer a well-articulated question.
3. Select or describe conclusions relevant to the question posed and supported by the data, especially conclusions about causes and effects.
4. Predict outcomes when properties or proximity of the objects are changed, given the inferred cause-and-effect relationships.
5. Describe, identify, gather, and/or select information needed to identify patterns that can be used to predict outcomes about the changes in energy.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-PS3-4
Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific ideas to solve design problems.</td><td>PS3.B: Conservation of Energy and Energy Transfer
• Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.

PS3.D: Energy in Chemical Processes and Everyday Life
• The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use.

ETS1.A: Defining Engineering Problems
• Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.</td><td>Energy and Matter
• Energy can be transferred in various ways and between objects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.

Content Limits
• Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Magnetic, motion, speed, conservation, gravitational, battery, conversion, properties, chemical.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Mass, net force, velocity, relative position, constant speed, direction of motion, direction of a force, deceleration, independent, economic, control, impact, inertia, Newton’s laws (1st, 2nd, 3rd), stationary, frame of reference, potential energy, mechanical energy, kinetic energy, conserve, relative, chemical energy.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering practices are built around meaningful design problems rather than phenomena. For this performance expectation, a design problem and associated competing solutions will replace phenomena.

Some examples of design problems for 4-PS3-4:</td></tr>
</table>

	• A front door does not have an alarm. Any alarm that is added needs to be heard in the back hallway. • A person hiking on a hot day needs to take a fan to stay cool. The fan must be small so that it does not add to the weight of the hiker's pack but must also last the entire hike. • The water in a house is heated with electricity purchased from a power company. A decision is made to instead heat the water using electricity generated with solar panels on the roof. The water heater must heat enough water to meet the needs of the home but the cost of installation and/or maintenance cannot exceed the family's budget. • A motor is added to a toy car for a race. The motor must be able to move the car across a room at a high speed.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Express or complete a causal chain explaining how energy can be transferred via electric current to produce light, sound, heat, and/or motion. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.
2. Identify evidence supporting the inference of causation that is expressed in a causal chain.
3. Use an explanation to predict how the motion, sound, heat, or light of an object changes, given a change in electrical energy—or, how the expression of energy will change, given a change in the conversion of stored energy.
4. Identify or assemble from a collection, including distractors, the relevant aspects of the problem that given design solutions, if implemented, will resolve/improve. The design solution must convert energy from one form to another within the content limits.
5. Using given information, select or identify constraints that the device that converts energy from one form to another must meet OR criteria against which it should be judged.
6. Using given information, design, propose, illustrate, assemble, test, or refine a potential device (prototype) that converts energy from one form to another.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-PS4-1
Develop a model of waves to describe patterns in terms of amplitude and wavelength, and that waves can cause objects to move.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model using an analogy, example, or abstract representation to describe a scientific principle.</td><td>PS4.A: Wave Properties
▪ Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach.
▪ Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks).</td><td>Patterns
• Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.
• Acceptable clusters may include: amplitude and wavelength, motion of an object, or both.

Content Limits
• Limited to physically visible mechanical waves.
• Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.
• Examples of objects being moved by waves are limited to up and down motion. Horizontal motion is above grade level due to the other factors involved.
• Don’t directly reference energy. Energy is addressed in 4-PS3.
• <u>Students do not need to know</u>:
○ Types of waves: sound, light, non-periodic, compression
○ Particle movement
○ Quantitative models
○ Behaviors of waves: absorption, reflection, refraction, transmission, interactions with different materials (angle of incidence, amount of reflection or absorption, light being refracted into colors). Reflection is limited to the concept. How waves are reflected and the details of reflection (as well as other behaviors) are covered in MS-PS4-2.
○ Wave calculations
○ Motion of objects in the ocean due to ocean currents</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Crest, trough, peak, rate, property, medium, period</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Electromagnetic, compression, particle, transmission, seismic wave, radio wave, microwave, infrared, ultraviolet, gamma rays, x-rays, angle of incidence, concave, convex, diffraction, constructive interference, destructive interference, resonance, refraction, absorption, reflection, pitch, sound wave, light wave.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/</td><td colspan="3">Some example phenomena for 4-PS4-1:</td></tr>
</table>

Phenomena	• A boat floating in the ocean is tied to a pier. The boat rises and falls with the waves. • Two students hold ends of a rope. One student lifts her end, and then drops it toward the ground. The rope forms a wave that travels from that student to the other student. • The sand waves on a windy beach get bigger and more pronounced over time. They are regular and evenly spaced. • A surfer riding a wave stays up if she moves along the wave but falls as soon as she stops moving.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Select or identify the components of a model that are needed to describe wave behavior, patterns of wave creation, and/or the motion of objects carried on/by waves. Components might include the source, amplitude, frequency, and/or wavelength.
2. Manipulate the components of a model to demonstrate properties, processes, and/or events that result in the patterns of wave behavior that are identified in the phenomenon. These patterns of wave behavior can include creation and replication of waves.
3. Describe, select, or identify the relationships among components of a model that describe wave behavior, patterns of wave creation, and/or the motion of objects carried on or by a wave.
4. Given a model of waves, illustrate the way in which the wave changes to yield a given result (more movement, less movement) and/or identify the result based on changes to the wave.
5. Make predictions about the effects of changes in model components (e.g., energy of wave source, distance from wave source), the amplitude or wavelength of a wave, or motion of objects affected by the wave. Item writer: Do not directly reference the energy of the wave source. Instead, show the speed and size of the object causing the wave, etc.

Performance Expectation	**4-PS4-2** Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.		
Dimensions	**Developing and Using Models** • Develop a model to describe phenomena.	**PS4.B: Electromagnetic Radiation** • An object can be seen when light reflected from its surface enters the eyes.	**Cause and Effect** • Cause-and-effect relationships are routinely identified.
Clarifications and Content Limits	**Content Limits** • Assessment does not include: o knowledge of specific colors reflected and seen; o the cellular mechanisms of vision; o how the retina works.		
Science Vocabulary Students Are Expected to Know	Energy, light ray, reflection, reflective, surface		
Science Vocabulary Students Are Not Expected to Know	Particle, transmission, angle of incidence, angle of reflection, concave, convex, diffraction, constructive interference, destructive interference, refraction, absorption, wave, field, illuminate, diffuse reflection, specular reflection, spectrum, prism.		
Phenomena			
Context/ Phenomena	Some example phenomena for 4-PS4-2: • A person can see a cat in the mirror. The cat is otherwise hidden from view. • A performance is being watched by a person. Another person stands up and blocks the view. • A flashlight is pointed at a door in a dark room. The door is the only object seen in the room. • The surface of a lake is very still. The reflection of a tree on the bank can be seen on the lake's surface.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
1. Identify the components needed to model the phenomenon. Components might include the light, the light source, the object, the path the light follows, and the eye.			
2. Complete an illustration or flow chart that is capable of representing how light reflecting from objects and entering the eye allows objects to be seen. This <u>does not</u> include labeling an existing diagram.			
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.			
4. Make predictions about the effects of changes in the model, particularly using mirrors, changing positions of light sources, objects, and the eye. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.			
5. Identify missing components, relationships, or other limitations of the model.			
6. Describe, select, or identify the relationships among components of a model that describe how light reflecting from objects and entering the eye allows objects to be seen.			

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<table>
<tr><td>Performance Expectation</td><td colspan="3">4-PS4-3
Generate and compare multiple solutions that use patterns to transfer information.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Generate and compare multiple solutions to a problem, based on how well they meet the criteria and constraints of the design solution.</td><td>PS4.C: Information Technologies and Instrumentation
• Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa.

ETS1.C: Optimizing the Design Solution
• Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.</td><td>Patterns
• Similarities and differences in patterns can be used to sort and classify designed products.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of solutions could include:
  • drums sending coded information through sound waves;
  • using a grid of 1’s and 0’s, representing black and white, to send information about a picture;
  • using Morse code to send text.

Content Limits
• <u>Students do not need to know:</u>
  o the different parts of the electromagnetic spectrum (visible, microwave, x-ray, radio wave, etc.);
  o binary coding or how it works;
  o that light is made up of an electric and magnetic field;
  o transverse vs. longitudinal waves;
  o how information gets encoded;
  o how different forms of communicating information work (Morse code vs. something like a telephone).</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Amplitude, wavelength, reflect, vibrate, vibration, absorb, properties, sound wave, wave, communicate, electricity, coded, Morse code, digital, store, transfer, convert.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Light emission, light refraction, transmit, wave peaks, light wave, electromagnetic, frequency, radiation, wave packet, light scattering, light transmission, electric field, magnetic field, photon, radio wave, x-ray, binary, electron, pixel, CCD, transverse, longitudinal.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 4-PS4-3:
• In July 2015, the New Horizons Space Probe flew past Pluto. The space probe is tasked with taking detailed pictures of Pluto so that scientists on Earth can study its features. However, the spacecraft can only send sequences of numbers back to Earth.</td></tr>
</table>

	• A man wants to send an urgent message to his wife who is a long distance away. It would take too long to drive to his wife and deliver the message himself. The only way he can communicate is through an electrical wire that is set up between the two locations. • Two people want to communicate a number 1 through 10 over a large distance. They have no telephones or other means of communication. They are close enough that they can see or hear each other, however, a river separates them so they cannot reach each other. • Two people want to communicate over a large distance. However, the power is out and so they cannot use the telephone. All they have is a string that is stretched between their two houses. Attached to the end of each string is a metal can. The messages they want to be able to send consists of numbers 1 through 10.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how each pattern is used to transmit information. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Use an explanation to compare the two solutions and select which one is better for the transmitting of information.
5. Describe, identify, and/or select information needed to support an explanation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-LS1-1
Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an argument with evidence, data, and/or a model.</td><td>LS1.A: Structure and Function
• Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.</td><td>Systems and System Models
• A system can be described in terms of its components and their interactions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin.

Content Limits
• Assessment is limited to macroscopic structures within plant and animal systems.
• The student does not need to know about cellular structures like the nucleus, mitochondria, the Golgi apparatus or the endoplasmic reticulum.
• <u>The student does not need to know:</u> about organ systems like the circulatory system, reproductive system, or nervous system.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Brain, body, flow, flower, heart, lung, muscle, movement, grasp, habit, moisture, organization, petal, predator, prey, roots, skin, stem, stomach, temperature</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Cell, detect, response, body plan, elastic, external, intellectual, internal, invertebrate, organ, vertebrate, multicellular, stimulus, tissue, enzyme, xylem, phloem, parenchyma, and cambium cells.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 4-LS1-1:
• In a field of grass, a butterfly lands on one of the only red poppy flowers in sight.
• A manta ray has a flat circular body. Its fins spread out like wings from its body.
• A pelican can hold up to 3 gallons of water in its pouch.
• A student sees a hollow, brown copy of a cicada insect attached to the bark of a tree.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify evidence or patterns in the data that support inferences and/or determine relationships between a particular structure of an organism and a function that supports survival, growth, behavior, and reproduction.</td></tr>
<tr><td colspan="4">2. Understand and generate simple bar graphs or tables to document patterns, trends, or relationships between a particular structure of an organism and a function that supports survival, growth, behavior, and reproduction.</td></tr>
</table>

3. Sort observations/evidence into those that appear to support or not support an argument.
4. Based on the provided data, identify or describe a claim regarding the relationship between a structure of an organism and a function that supports survival, growth, behavior, and reproduction.
5. Summarize or organize given data or other information to support or refute a claim regarding an organism's structure and its function.
6. Sort, tabulate, classify, separate, and/or categorize relevant from irrelevant information regarding an organism's structure and its function.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-LS1-2
Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model to test interactions concerning the functioning of a natural system.</td><td>LS1.D: Information Processing
• Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal's brain. Animals are able to use their perceptions and memories to guide their actions.</td><td>Systems and System Models
• A system can be described in terms of its components and their interactions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on systems of information transfer.

Content Limits
• Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Lens, vision, hearing, muscle, ear, middle ear, outer ear, inner ear, eardrum, response, habitat, eye, lens, memory</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Sensory, brain, cells, retina, pupil, saliva, salivary gland, vibration, cornea, iris, brainstem, consumer, nerve, optic nerve, nerve cell, nerve tissue, nerve impulse, connecting nerve, nerve fiber, organ system, reflex, reflex action, reaction time, cue.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 4-LS1-2:
• A bear cub in the woods cries out. Its mother immediately runs toward it.
• A deer walks in the woods. It turns suddenly and moves off in a different direction. A few minutes later, a skunk appears from the bushes.
• A cat sits on a stone wall. A mouse appears at the base of a nearby tree. The cat springs after the mouse.
• A hawk flies overhead. Suddenly, it dives toward the tall grass. A moment later, it returns to the sky, a snake in its claws.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components the components needed to model the phenomenon. Components might represent organ systems or parts of a system needed for collection and/or processing of sensory information.</td></tr>
<tr><td colspan="4">2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing the flow and/or processing of sensory information in an animal. This <u>does not</u> include labeling an existing diagram.</td></tr>
</table>

3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.*
4. Given models or diagrams of the flow and/or processing of sensory information in an animal, identify responses to sensory inputs and how they change in each scenario OR identify the properties of organs and/or organ systems that allow animals to respond to sensory information.*
5. Identify missing components, relationships, or other limitations of a model that shows the flow and/or processing of sensory information in an animal.
6. Describe, select, or identify the relationships among components of a model that describe how sensory information is processed or explain how an animal responds to sensory inputs.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-ESS1-1
Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Identify the evidence that supports particular points in an explanation.</td><td>ESS1.C: The History of Planet Earth
• Local, regional, and global patterns of rock formations reveal changes over time due to Earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed.</td><td>Patterns
• Patterns can be used as evidence to support an explanation.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Examples of evidence from patterns could include rock layers with marine shell fossils above rock layers with plant fossils and no shells, indicating a change from land to water over time, and a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock.

Content Limits
• Assessment does not include specific knowledge of the mechanism of rock formation or memorization of specific rock formations and layers.
• Assessment is limited to relative time.
• Assessment does not include earthquakes—the clarification statement focuses on geomorphology and landscape change through time. The focus is not on tectonics, despite its mention in the DCI.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Weathering, erode, glacier, climate, fossil, landscape, shell, river, mountain, canyon, deposit, marine.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Rock strata, ocean basins, glaciation, watersheds, geological, mountain chains, igneous rock, metamorphic rock, sedimentary rock, terrestrial, aquatic.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Sample phenomena for 4-ESS1-1:
• The rock walls on both sides of the Grand Canyon contain layers with marine fossils, interspersed with layers containing terrestrial fossils.
• Church Rock, New Mexico, is a very dry place far from the sea. However, exposures of rocks in the area contain many fossils of marine organisms.
• Axel Heiberg Island in the Canadian Arctic is too cold for trees to grow. However, sedimentary rocks on the island preserve hundreds of fossil stumps from large evergreen trees.
• Sihetun, China, is dry and mountainous. Sedimentary rocks exposed in the area preserve thousands of fish fossils. These sedimentary rocks are sandwiched between lava flow rocks. There are no active volcanoes in this part of China.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Describe, identify, and/or select evidence from patterns of rock formations and/or patterns of fossils in rock layers to support the explanations of changes in the landscape over time.
2. Express or complete a causal chain explaining changes in patterns of fossils in rock layers.
3. Identify patterns of rock formations and/or patterns of fossils in rock layers.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-ESS2-1
Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.</td><td>ESS2.A: Earth Materials and Systems
• Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified, tested, and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Examples of variables to test could include: angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.

Content Limits
• Students aren’t expected to know the flow of energy that causes the phenomena.
• Assessment is limited to one form of erosion.
• Assessment does not include chemical erosion.
• <u>Students do not need to know</u>: Sedimentation, Earth’s interior, crystallization, minerals, the rock cycle, dynamic forces, feedback interactions, constructive forces, or deformation.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Erosion, freeze, movement, cycle, weathering, ocean, sediment, vegetation, particle, earthquake, volcanoes, thaw.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Composition, slope, continental boundaries, trench, minerals, plate tectonics, topography.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 4-ESS2-1:
• Rocks in the bottom of a river are usually smooth, but the rocks sitting on the ground nearby often have sharp edges and corners.
• Near its start in Colorado, the bed of the North Platte River is covered with boulders. Some five hundred miles away in Nebraska, the bed of the river is mostly sand.
• New gullies appear in a gravel driveway after a heavy rain.
• Over the course of a summer there is a series of major storms. At the end of the season, the channel of a small stream running through a grassy park is significantly wider than it was before the storms.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify the factors that affect weathering or the rate of erosion by water, ice, wind, or vegetation.</td></tr>
</table>

2. Identify from a list the materials/tools needed for an investigation of how wind affects the factors that affect weathering or the rate of erosion by water, ice, wind, or vegetation.
3. Identify, among distractors, the outcome data that should be collected in the investigation.
4. Make and/or record observations about how input factors affect relevant outcomes while using fair tests in which variables are controlled.*
5. Make or communicate the conclusions from the investigation. Conclusions will be causal relationships.**

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD5 can be used ONLY if used in concert with TD4

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-ESS2-2
Analyze and interpret data from maps to describe patterns of Earth’s features.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to make sense of phenomena using logical reasoning.</td><td>ESS2.B: Plate Tectonics and Large-Scale System Interactions
• The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes appear in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth.</td><td>Patterns
• Patterns can be used as evidence to support an explanation.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Maps can include topographic maps of Earth’s land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.

Content Limits
• <u>Students do not need to know:</u> the tectonic processes that form Earth’s features.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Earthquake, Earth’s surface, crust, volcanic eruption, region, barrier, global, local, physical characteristic, ocean, force, landscape, mountain chain, mountain range, continental boundary, sea floor, collide, properties, ocean trench, pressure, topographic map.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Geologic, impact, magnitude, frequency, sediment deposition, ancient, ocean basin, rock layer movement, formation, continental shelf, deform, density, tectonic process, distribution, oceanic crust, plate boundary/collision, seafloor spreading.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation, the phenomena are the patterns of features on maps that the student examines. These patterns can sometimes be described with simple statements as shown below, but the actual phenomenon in each case is the pattern on the map. If descriptive statements are used, writers must be careful not to give the pattern or the point of the cluster away to the student.

Some example phenomena for 4-ESS2-2:
• There are active volcanoes in Alaska. There are no active volcanoes near Buffalo, New York. (If this statement were to be used to describe the map, then the students task would have to be something more than simply pointing out that there are volcanoes in Alaska and none near Buffalo, such as figuring out that Alaska is closer to a tectonic plate boundary than is New York.)
• Earthquakes occur often in western South America. Earthquakes almost never occur on the eastern side of the continent. (If this statement were to be used to describe the map, then the student’s task would have to be something more than simply pointing out that there are earthquakes on the eastern side more often than the western, such as figuring out that a plate boundary lies along the eastern coast of South America.)
• Many volcanoes are found in a ring around the Pacific Ocean. There are fewer found on the edges of the Atlantic Ocean. (If this statement were to be used to describe the map, then</td></tr>
</table>

	the students task would have to be something more than simply pointing out that there are many volcanoes around the Pacific and few around the Atlantic, such as figuring out that tectonic plate boundaries surround the Pacific Ocean.) • There are no mountain ranges in Kansas. There are many mountains in Washington State. (If this statement were to be used to describe the map, then the students task would have to be something more than simply pointing out that there are mountains in Washington and none in Kansas, such as figuring out that Washington is closer to a tectonic plate boundary than Kansas.)

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize, arrange, or summarize map data and/or symbols to highlight/describe patterns of geological features on Earth's surface.**
2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels, of map data that document patterns of geological features on Earth's surface. This may include sorting out distractors.*
3. Use relationships identified in the presented map data to predict the location of geological features on Earth's surface, such as mountain ranges, volcanoes, earthquake foci, and deep ocean trenches.*
4. Identify evidence or patterns in map data that support inferences about the patterns of geological features on Earth's surface.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD1 may be used in combination with 2, 3, or 4 for stand-alone development.

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-ESS3-1
Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Obtain and combine information from books and other reliable media to explain phenomena</td><td>ESS3.A: Natural Resources
• Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of renewable energy resources could include:
o Wind energy
o Water behind dams
o Sunlight
• Examples of non-renewable energy resources are:
o fossil fuels
o fissile materials
• Examples of environmental effects could include:
o Loss of habitat due to dams
o Loss of habitat due to surface mining
o Air pollution from burning of fossil fuels

Content Limits
• The following things should be avoided:
o Casting fossil fuels in a negative light and alternative fuels in a positive light
o Pros and cons of one energy source vs. another
o Negative effects of extracting and burning coal
o Negative effects of fracking
o Cause and effect of acid rain
o The term “global warming”
o <u>Students do not need to know:</u> how natural resources are used to generate energy (scientific specifics regarding how burning coal creates energy/how wind produces energy etc.).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Recycle, reuse, coal, habitat, pollution, dam, population, atmosphere, oil, resource, fossil fuel, renewable, nonrenewable, conservation</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Agricultural, biosphere, mineral, geological, hydrothermal, metal ore, organic, deposition, petroleum, derive, extract, natural gas, oil shale, sustainability, tar sand</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 4-ESS3-1
• A pipeline is built to transport oil from one location to another. As the oil moves across the landscape it leaks into a river along the way.</td></tr>
</table>

	• The Three Gorges dam was built along the Yangtze River in China to generate electricity. The Chinese dove tree lives along the Yangtze River. Building the dam affected this tree. • Several wind turbines are placed in a field to provide electricity to neighboring areas. To do this, forest land had to be cut down to provide space for the wind turbines. • Oil can be used to generate electricity. Oil can be found under the ocean. Seismic waves are used to locate the oil. Because of this, 100 melon head whales were displaced off the coast of Madagascar.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data/information to highlight trends, patterns, or correlations.
2. Express or complete a causal chain explaining how energy and fuel that are derived from natural resources affect the environment. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.*
4. Identify patterns or evidence in the data that supports inferences about the effects that the usage of certain natural resources has on the environment.
5. Describe, identify, and/or Select information needed to support an explanation.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">4-ESS3-2
Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Generate and compare multiple solutions to a problem based on how well they meet the criteria and constrains of the design solution</td><td>ESS3.B: Natural Hazards
• A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts.

ETS1.B: Designing Solutions to Engineering Problems
• Testing a solution involves investigating how well it performs under a range of likely condition (secondary)</td><td>Cause and Effect
• Cause and effect relationships are routinely identified, tested, and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.

Content Limits
• Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Environment, nature, recycle, reuse, coal, habitat, pollution, dam, population, atmosphere, oil, resource, fossil fuel, renewable, nonrenewable, conservation</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Agricultural, biosphere, mineral, geological, hydrothermal, metal ore, organic, deposition, petroleum, derive, extract, natural gas, oil shale, sustainability, tar sand</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering performance expectations are built around meaningful design problems rather than phenomena. In this case, the design problems involve reducing the impact of earthquakes, floods, tsunamis, and volcanic eruptions on humans. For this performance expectation, the design problem and competing solutions replace phenomena.

Example phenomena for 4-ESS3-2:
• Hurricanes generate high winds. Several building designs are being considered to construct buildings that could withstand the force of the wind.
• Eyjafjallajokull is an active volcano in Iceland. In preparation for future volcanic activity, several evacuation routes are being considered.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data/information to highlight trends, patterns, or correlations in data regarding human activity and natural hazards.</td></tr>
</table>

2. Express or complete a causal chain explaining how humans can reduce the impact of natural hazards.
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Identify patterns or evidence in the data that supports inferences about the ways humans can reduce impacts of natural hazards.
5. Use an explanation to compare the two solutions and select which one is better for addressing the problem of the impact of natural hazards on humans and explain how well each solution meets the criteria and constraints of the design solution.
6. Describe, select, or identify components of competing design solutions.

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-PS1-1
Develop a model to describe that matter is made of particles too small to be seen.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use models to describe phenomena.</td><td>PS1.A: Structure and Properties of Matter
• Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects.</td><td>Scale, Proportion, and Quantity
• Natural objects exist from the very small to the immensely large.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of evidence supporting a model could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.

Content Limits
• Assessment does not include the atomic-scale mechanism of evaporation and condensation or the defining of the unseen particles.
• Students are expected to know that matter can neither be destroyed nor created.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Substance, particle, solid, liquid, gas, vapor, steam, air, phase change, evaporate, boil, condense, freeze, melt, dissolve, mixture, chemical reaction, energy.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Atom, compound, molecule, chemical bond, solution, homogenous, heterogeneous, colloid, solute, solvent, precipitant, precipitate, reactant, product, air pressure, law of conservation of matter.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-PS1-1:
• A hissing sound can be heard as a bicycle wheel deflates.
• A sour odor can be smelled from milk that has been kept too long (or expired).
• When you pump air out of a closed bottle that is partially filled with marshmallows, the marshmallows expand in size. However, when you open the bottle, the marshmallows shrink back to their original size.
• When you place a lit match into a glass bottle and a boiled egg is set on the bottle opening, the egg eventually gets sucked into the bottle.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include solid, liquid, or gas particles; particles of different substances; and representations of particle movement.</td></tr>
</table>

2. Assemble or complete — from a collection of potential model components — an illustration, flow chart, or causal chain that is capable of representing the particle nature of matter. This does not include labeling an existing diagram.
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
4. Make predictions about the effects of changes in the movements of, distances between, or phases of the particles of matter under investigation. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Provided with models or diagrams of the particles of matter under investigation, identify the properties of the particles under investigation and how they change in each scenario. The properties of the particles may include the relative motions of, distances between, and phases of the particles.
6. Describe, select, or identify the relationships among components of a model that explains the observed effects of the particle nature of matter.

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-PS1-2
Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Measure and graph quantities such as weight to address scientific and engineering questions and problems.</td><td>PS1.A: Structure and Properties of Matter
• The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish.

PS1.B: Chemical Reactions
• No matter what reaction or change in properties occurs, the total weight of the substances does not change.</td><td>Scale, Proportion, and Quantity
• Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of reactions or changes could include mixing, dissolving, and phase changes that form new substances.

Content Limits
• Assessment does not include distinguishing mass and weight.
• <u>Students do not need to know:</u> structure of atoms, specific chemical equations.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Weight, substance, matter, conservation, temperature, mixing, phase change, dissolving, properties, reaction, particles, gas, solid, liquid.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Mass, atoms, molecules, rates.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-PS1-2:
• A cup of water is taken out of the freezer and left on a counter. After some time, the frozen water melts.
• A cup of hot tea can dissolve more sugar than a cup of cold tea, but they both weigh the same after the mixing is complete.
• When mixed together, silver nitrate and sodium chloride forms a white solid that weighs the same as the individual silver nitrate and sodium chloride weighed.
• When water, baking soda, and calcium chloride are mixed inside a freezer bag, the bag gets hot and expands. The expanded freezer bag weighs the same as the ingredients did when they were separate.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Make simple calculations using given data to calculate or estimate the total weight of a substance after heating, cooling, or mixing.</td></tr>
<tr><td colspan="4">2. Measure or graph data that can be used to calculate or estimate the total weight of a substance after heating, cooling, or mixing.</td></tr>
</table>

3. Describe and/or summarize data (e.g., using illustrations and/or labels) to identify/highlight trends, patterns, or correlations concerning the weight of the substances being investigated at the beginning and end of an investigation.
4. Compile and/or select, from given information, the particular data needed for a specific inference about the total weight of substances. This can include sorting out the relevant data from the overall body of given information.
5. Select, describe, or illustrate a prediction made by applying the findings from measurements or an investigation.
6. Use relationships identified in the data to explain that regardless of the type of change, the total weight of matter is conserved.

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-PS1-3
Make observations and measurements to identify materials based on their properties.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.</td><td>PS1.A: Structure and Properties of Matter
• Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.)</td><td>Scale, Proportion, and Quantity
• Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids.
• Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility.

Content Limits
• Assessment does not include density or distinguishing between mass and weight.
• <u>Students do not need to know:</u> chemical reaction equations, balancing reaction equations, atomic-level processes.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Electric, electrically charged, magnetic, magnetic attraction, conductor, change of state, substance, absorbency, evaporate, metal, vapor, conduction, relative, conservation of matter, phase change, dissolve, react, product</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Insulator, element, reaction, boiling point, melting point, molecule, forms of matter, reactant, chemical compound, chemical reaction, atom</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-PS1-3:
• Sugar and flour are white powdery substances. Sugar is soluble in water and flour is not.
• Three mineral crystals sit on a table. The three crystals are all the same color, resembling clear glass. However, they are all different minerals. One of them is quartz, one of them is halite, and the third is calcite.
• Two nails are on a table. When a magnet is placed over the nails, one of them moves from the table and sticks to the magnet.
• Two pieces of wood are hit with a hammer. One piece of wood has a depression/dent where the hammer hit it. The other does not have a dent/depression.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Identify from a list, including distractors, the materials or tools needed to observe or measure properties of matter to identify unknown materials.
2. Identify from a list, including distractors, the output data needed to identify or differentiate materials. **
3. Make and/or record observations or measurements from the investigation of the properties of materials.*
4. Interpret and/or communicate the data from the investigation of the properties of materials.
5. Make or communicate conclusions from the investigation of the properties of materials.

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD2 may be used for stand-alone item if used with TD3

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-PS1-4
Conduct an investigation to determine whether the mixing of two or more substances results in new substances.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials are considered.</td><td>PS1.B: Chemical Reactions
• When two or more different substances are mixed, a new substance with different properties may be formed.</td><td>Cause and Effect
• Cause-and-effect relationships are routinely identified and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Students are not expected to be able to balance chemical equations, but should be able to complete simple mathematical (addition and subtraction) calculations in regard to starting materials and ending materials.

Content Limits
• Students are expected to know that matter is neither destroyed nor created.
• <u>Students do not need to know:</u> Chemical names, chemical symbols, general balanced equation {reactant + reactant → products}, and isotopes, specific chemical reaction types (e.g. oxidation, reduction, decomposition, and combustion).</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Matter, substance, particle, chemical property, physical property, mass, volume, density, melting point, boiling point, freezing point, dissolve, flammable, odor, gas, solid, liquid, mixture, chemical reaction, gram(s), physical change, chemical change.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Reactant, product, atom, molecule, compound, chemical bond, law of conservation of mass, law of conservation of energy, intramolecular attractions, intermolecular attractions, solubility, solvent, solute, precipitant, rate of chemical reaction, acid, base, salt (as an ionic crystal), fusion, fission, homogeneous mixture, heterogeneous mixture, plasma, pH.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-PS1-4:
• A peach shrivels and becomes covered with mold.
• Over time, one metal changes color when exposed to rainwater. However, another metal exposed to rainwater does not.
• A bottle partially filled with vinegar sits on a counter. An empty balloon is partially filled with baking soda. When the open end of the balloon is stretched over the bottle top, a hissing/fizzing sound can be heard and the balloon expands.
• When sugar crystals are added to vinegar in a bowl, the crystals disappear. When crystals of baking soda are added to vinegar in a bowl, the mixture begins to bubble and foam.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
</table>

1. Identify from a list, including distractors, the properties that should be tested or the materials/tools needed in an investigation of the physical and chemical properties of the starting and ending substances involved in mixing.
2. Identify the outcome data that should be collected in an investigation of the physical and chemical properties of the starting and ending substances under investigation.
3. Make and/or record observations/data about the physical and chemical properties of the substances that are mixed and the substances resulting from the mixture.
4. Interpret and/or communicate the data from an investigation. This may include identifying/describing trends, patterns, or correlations among observations and data concerning the physical and chemical properties of the beginning and ending substances being investigated.
5. Explain or describe the causal processes that lead to the observed data.

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-PS2-1
Support an argument that the gravitational force exerted by Earth on objects is directed down.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Support an argument with evidence, data, or a model.</td><td>PS2.B: Types of Interactions
• The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.</td><td>Cause and Effect
• Cause and effect relationships are routinely identified and used to explain change.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• "Down" is a local description of the direction that points toward the center of the spherical Earth.

Content Limits
• Assessment does not include mathematical representation of gravitational force.
• Study of gravity is limited to gravity on Earth.
• <u>Students do not need to know</u>: Calculations for weight (weight = mass • gravity), free fall, terminal velocity, weightlessness, air resistance, friction, black holes, inertia, Newton's law of universal gravitation, vacuum.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Sun, gravity, space, flow, magnet, period (time), charge, Earth's rotation, solar system, spherical, exert, transfer, mass, orbital, mass, volume</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Attractive, direction of force, direction of motion, field, linear, nonlinear, gravitational energy, gravitational field, magnetic field, permeate.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Sample phenomena for 5-PS2-1:
• A hard rubber ball dropped in a pool falls more slowly than the same ball dropped on land.
• A feather released on top of a cliff on a breezy day seems to fly away, while a similar feather dropped on flat ground on a breezy day lands on the ground.
• A small piece of clay set on the top of a globe stays in place, but when you put it on the bottom of the globe it drops off. A piece of clay put at the real north pole stays in place, and also stays in place on the real south pole.
• A basketball flies in an arc before going through the basket.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Sort observations into those that appear to support competing (given) arguments, or into those that support, contradict, or are not relevant to a given argument. Observations are from animations, simulations, or other given material.</td></tr>
<tr><td colspan="4">2. Sort, tabulate, classify, separate, and/ or categorize relevant from irrelevant evidence (observations) or data.</td></tr>
<tr><td colspan="4">3. Select from a given collection additional relevant observations that would help distinguish between competing arguments or the veracity of a single argument.</td></tr>
</table>

4. Select, identify, or describe apparent counterexamples to a supported argument.
5. Identify from a given collection or explain in writing flaws in observation that lead to an apparent counterexample, or explain the counterexample in terms of grade-level appropriate properties gravity, or other simple forces from earlier grade levels.
6. Sort statements into categories such as facts, reasonable judgments based on available facts, and speculation.
7. Clearly articulate the evidence supporting and contradicting an argument, noting how the evidence supports or contradicts the argument (hand scored).*
8. Predict outcomes when properties or proximity of the objects are changed, given the inferred cause and effect relationships. This can be done by describing outcomes, or selecting or identifying outcomes from lists.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-PS3-1
Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use models to describe phenomena.</td><td>PS3.D: Energy in Chemical Processes and Everyday Life
• The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter.

LS1.C: Organization for Matter and Energy Flow in Organisms
• Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion. (secondary)</td><td>Energy and Matter
• Energy can be transferred in various ways and between objects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of models could include diagrams and flow charts.

Content Limits
• Assessment does not include photosynthesis.
• <u>Students do not need to know:</u> photosynthesis equation</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Energy, matter, transfer, light</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Photosynthesis, metabolism, atoms, chemicals, reaction, radiation</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-PS3-1:
• Cows eat grass that grew in the sun.
• Termites eat the wood in trees.
• Caterpillars eat leaves and grow big.
• Koalas mainly eat eucalyptus leaves.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify, from a collection of potential model components, including distractors, the parts of a model need to describe the flow of energy among plants, animals, and the sun.</td></tr>
<tr><td colspan="4">2. Assemble or complete a model representing the flow of energy among plants, animals, and the sun.</td></tr>
<tr><td colspan="4">3. Manipulate the components of a model to demonstrate properties, processes, and/or events that result in the flow of energy among plants, animals, and the sun, including the relationships of organisms and/or the cycles of energy and/or matter.</td></tr>
</table>

4. Articulate, describe, illustrate, select, or identify the relationships among components of a model that describe the movement of matter among plants, animals, and the sun.
5. Make predictions about the effects of changes in model components including the substitution, elimination, or addition of energy and/or an organism and the result.

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<table>
<tr><td>Performance Expectation</td><td colspan="3">5-LS1-1
Support an argument that plants get the materials they need for growth chiefly from air and water.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Support an argument with evidence, data, or model.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• Plants acquire their material for growth chiefly from air and water.</td><td>Energy and Matter
• Matter is transported into, out of, and within systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.

Content Limits
• Assessment does not include photosynthesis or the photosynthesis reaction equation. Students should know that plants carry out photosynthesis for energy, but they do not need to know the specifics of the process or equation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Organism, algae, atmosphere, consumer, cycle, matter, product, transport, chemical, convert, transfer, energy flow, flow chart, conservation, nutrients.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Plant structure, producer, chemical process, carbon, carbon dioxide, aerobic, anaerobic, molecule, sugars, photosynthesis</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-LS1-1:
• A neoregelia plant sits on the branch of a much larger kapok tree in the Cloud Forest of South America.
• A plant grows in a classroom and the students weigh the soil every day. The weight of the soil does not change over time but the plant continues to grow.
• Spanish moss hangs from the branches of a live oak tree in the swamps of Louisiana.
• Strawberries sold in a supermarket were grown inside of a greenhouse without soil.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Sort observations into those that appear to support competing (given) arguments, or into those that support, contradict, or are not relevant to a given argument. Observations are from animations, simulations, or other given material.</td></tr>
<tr><td colspan="4">2. Sort, tabulate, classify, separate, and/or categorize relevant from irrelevant evidence (observations) or data.</td></tr>
<tr><td colspan="4">3. Select from a given collection additional relevant observations that would help distinguish between competing arguments or the veracity of a single argument.</td></tr>
<tr><td colspan="4">4. Select, identify, or describe apparent counterexamples to a supported argument.</td></tr>
</table>

5. Identify from a given collection—or explain in writing—flaws in observation that lead to an apparent counterexample, or explain the counterexample in terms of grade-level appropriate properties of plant growth.
6. Sort statements into categories such as facts, reasonable judgments based on available facts, and speculation.
7. Articulate the evidence supporting and/or contradicting an argument that plants chiefly need air and water for growth.

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-LS2-1
Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model to describe phenomena.</td><td>LS2.A: Interdependent Relationships in Ecosystems
• The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plant parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases and water from the environment and release waste matter (gas, liquid, or solid) back into the environment.</td><td>Systems and System Models
• A system can be described in terms of its components and their interactions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food.
• Examples of systems could include organisms, ecosystems, and Earth.

Content Limits
• <u>Assessment does not include</u>: molecular explanations.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Organism, bacteria, fungus, algae, gas, nutrients, producer, consumer, decomposer, cycle, conserve, products, relationship, waste, recycle, species, balance</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Chemical process, reaction, molecule, carbon, carbon dioxide, oxygen, sugar, aerobic, anaerobic, photosynthesis</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-LS2-1:
• Insects in a terrarium only survive when bacteria and plants are present.
• A new fish tank must rest for 2–3 weeks with water before introducing fish or the fish die.
• Under a microscope, a sample of soil contains many bacteria, but a sample of desert sand does not.
• Farmers put fish in stock tanks to keep them clean.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components, including distractors, the parts of a model needed to describe the movement of matter among plants, animals, decomposers, and the environment.*	
2. Manipulate the components of a model to demonstrate properties, processes, and/or events that result in the movement of matter among plants, animals, decomposers, and the environment, including the relationships of organisms and/or the cycle(s) of matter and/or energy.	
3. Articulate, describe, illustrate, select, or identify the relationships among components of a model that describe the movement of matter among plants, animals, decomposers, and the environment.	
4. Make predictions about the effects of changes in model components, including the substitution, elimination, or addition of matter and/or an organism and the result.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-ESS1-1
Support an argument that the apparent brightness of the sun and stars is due to their relative distances from Earth.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Support an argument with evidence, data, or a model.</td><td>ESS1.A: The Universe and Its Stars
• The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.</td><td>Scale, Proportion, and Quantity
• Natural objects exist from the very small to the immensely big.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• Assessment is limited to relative distances, not sizes, of stars.
• Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage, etc.).
• Assessment does not include absolute brightness.
• <u>Students do not need to know:</u>
o Specific stars and their names.
o Luminosity and how that is affected by the size/age of a star.
o Flux or how to calculate it.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Space, planet, sun’s size, solar system, moon, burn, star brightness, constellation, galaxy, visible, astronomical.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Lunar phase, eclipse, celestial, mass, comet, light year, astronomical unit, emit, interstellar, fission, fusion, radiation, spectrum, star size, star composition, star formation, star types, luminosity, flux.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-ESS1-1:
• Most stars cannot be seen during the daytime but can be seen at night.
• The sun is never seen at the same time as other stars in the sky.
• Alpha Centauri A is larger than the sun but does not look as bright in the sky.
• Street lights that are farther away from you look dimmer.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize, arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in how the brightness of stars is based on their relative distance from Earth.*</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in how the brightness of stars is based on their relative distance from Earth. This may include sorting out distractors.*</td></tr>
<tr><td colspan="4">3. Describe, identify, and/or select information needed to support an explanation.*</td></tr>
<tr><td colspan="4">4. Use relationships identified in the data to predict the distance of a star depending on its brightness, or vice versa.*</td></tr>
</table>

5. Identify patterns or evidence in the data that supports inferences about how the brightness of stars depends on their relative distance from Earth.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

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<table>
<tr><td>Performance Expectation</td><td colspan="3">5-ESS1-2
Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Represent data in graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.</td><td>ESS1.B: Earth and the Solar System
• The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year.</td><td>Patterns
• Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• Examples of patterns could include the position and motion of Earth with respect to the sun and selected stars that are visible only in particular months.
• While the names of celestial objects, stars, or constellations can be included, students are not expected to identify them.
• Objects to be used to assess this PE are limited to the sun, Earth’s moon, Earth, and stars/constellations visible in Earth’s night sky.
• “Positions of the moon” refers to its location in Earth’s sky and not its appearance (phase).
• Assessment does not include cause of seasons, lunar phases, or the position of the sun in the sky throughout the year.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Circular motion, universe, Earth’s rotation, galaxy, axis, solar system, Milky Way, constellation, moon phases, lunar astronomical, orbit, tilt, annual, rotation, revolution.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Eclipse, celestial, comet, light year, astronomical unit, stellar.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-ESS1-2:
• The shadow cast by a sundial changes position and size throughout the day.
• A constellation that is viewed right above someone’s house at 8:00 p.m. one night can no longer be seen at 8:00 p.m. in a few months.
• The sun is seen in the sky only during the day
• It gets dark out after the sun goes below the horizon.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize, arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in how the data changes over time.*</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or groups of illustrations and/or labels of data that document patterns, trends, or correlations in how the data change over time. This may include sorting out distractors.*</td></tr>
</table>

3. Use relationships identified in the data to predict whether or not the pattern will continue OR how the data will look at some time in the future.*
4. Identify patterns or evidence in the data that supports inferences about the phenomena.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-ESS2-1
Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model using an example to describe a scientific principle.</td><td>ESS2.A: Earth Materials and Systems
• Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.</td><td>Systems and System Models
• A system can be described in terms of its components and their interactions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere.
• The geosphere, hydrosphere, atmosphere, and biosphere are each a system.

Content Limits
• Assessment is limited to the interactions of two systems at a time.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">core, mantle, crust, solid, liquid, gas, vapor, tundra, boreal forest, deciduous forest, grassland, desert, savannah, tropical rainforest, freshwater, marine, high pressure, low pressure, currents, circulation</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">troposphere, stratosphere, mesosphere, thermosphere, ionosphere, chaparral</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for 5-ESS2-1:
• The land area found on the beaches around Nantucket Sound in 2016 were about three times the land area in the same location in 1984.
• In 2016, Tucson, Arizona received more rain between June and September than Yuma, Arizona received during the entire year.
• The amount of carbon dioxide in the atmosphere measured at Mauna Loa Observatory in April is 397 parts per million. The amount measured at the same location the previous September was 2% less.
• In 1980, the salt content in the freshwater Biscayne Aquifer in Florida was 50 milligrams per liter. In 1997, the salt content of the same water was 1,000 milligrams per liter.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include labels, text, steps in a process.</td></tr>
</table>

2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing how the geosphere, biosphere, hydrosphere, and/or atmosphere interact. This does not include labeling an existing diagram. 3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
4. Make predictions about the effects of changes in the geosphere, biosphere, hydrosphere, or atmosphere on each other. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Given models or diagrams of ways in which the geosphere, biosphere, hydrosphere, and/or atmosphere interact, identify relationships between the spheres and how a change in one causes a change in another.
6. Identify missing components, relationships, or other limitations of the model.

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-ESS2-2
Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Describe and graph quantities such as area and volume to address scientific questions.</td><td>ESS2.C: The Roles of Water in Earth's Surface Processes
• Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.</td><td>Scale, Proportion, and Quantity
• Standard units are used to measure and describe physical quantities such as weight and volume.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere.
• Students will not be provided a calculator.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Cycle, fresh water, glacial movement, global, ground water, moisture, polar ice caps, properties of soil, reservoir, soil composition, water capacity, feature, glacial, hydrosphere, surface feature, water cycle, wetland.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Coastal, crust, internal, distribution, hydrological cycle, percentage</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">The phenomenon for these PEs are the given data. Samples of phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc.). For this performance expectation the phenomena are a set of data on the relative volume of water in different reservoirs on Earth using standard units for weight or volume.

Some example sets of data for 5-ESS2-2:
• Melting ice from the Arctic ice cap is currently adding fresh water to the very salty Arctic Ocean.
• Melting ice from the Greenland Ice Sheet is currently adding fresh water to the very salty Arctic Ocean.
• The Potomac River in the eastern United States is tidally influenced over XX% of its length. This tidal influence from the ocean results in the portion of the river near the ocean being a mixture of salt and fresh water and the portion of the river far from the ocean being fresh water.
• Salt water intrusion on Cape Cod, Florida, or California.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate relationships between the relative volumes of water in different reservoirs on Earth.</td></tr>
</table>

2. Calculate or estimate properties or relationships of the relative volumes of water in different reservoirs on Earth, based on data from one or more sources.
3. Compile, from given information, the data needed for a particular inference about the relative volumes of water in different reservoirs on Earth. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">5-ESS3-1
Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.</td><td>ESS3.C: Human Impacts on Earth Systems
• Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments.</td><td>Systems and System Models
• A system can be described in terms of its components and their interactions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3"></td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Atmosphere, cycle, fresh water, global, ground water, moisture, polar ice caps, properties of soil, soil composition, water cycle</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Coastal, crust, internal, distribution, hydrological cycle, reservoir, glacial movement, water capacity, glacial, hydrosphere, reservoir, feature, surface feature, wetland, percentage</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering practices are built around meaningful design problems rather than phenomena. For this PE, there are 2 phenomena and 2 design problems.

Some example phenomena for 5-ESS3-1:
• In England in 1965, there were about 182,000 bee colonies. By 2010, there were about 83,000 bee colonies.
• There is a haze in the air in Beijing, China’s capital city, which makes it hard to see long distances. The haze becomes worse on cold winter days.

Some example design problems for 5-ESS3-1:
• A company is going to put a new logging road in an area where grizzly bears live. The US Forest Service tells them that they need to pay attention to where they are going to put the road. The path of the road should be chosen so that it doesn’t disturb grizzly bear habitat very much.
• A flower garden to attract honeybees is being built. The type and color of flowers, garden placement, flower placement, and other features are chosen to attract honeybees.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify, evaluate, combine, organize, and/or communicate information (from texts, illustrations, animations, simulations, tables, or graphs) that is needed to make an informed decision related to human impacts on natural systems, solve a particular design problem, or complete a specified task.</td></tr>
</table>

2. Assemble or complete an illustration, graph, set of labels, or a flow chart that shows how the various pieces of information, which are needed to make an informed decision, solve a particular design problem, or complete a specified task, are interrelated. This does not include labeling an existing diagram.
3. Identify patterns or evidence in the data that supports inferences about human impacts on natural systems or a particular solution to a design problem or task.
4. Examine, identify or select positive or negative effects/implications of a community idea or design problem. This would include identifying potential positive or negative effects, especially when dealing with design solutions, and classifying the effects/implications as positive or negative and supporting those classifications with the relevant data.
5. Formulate a design or make an inference or conclusion, based on identified or combined information, evidence or data related to human impacts on natural systems, solution of a particular design problem, or completion of a specified task.
6. Evaluate a design or make an inference or conclusion, based on identified or combined information, evidence or data related to human impacts on natural systems, solution of a particular design problem, or completion of a specified task.

Specifications for Middle School

Introduction

This document presents *cluster specifications* for use with the Next Generation Science Standards (NGSS). These standards are based on the Framework for K-12 Science Education. The present document is not intended to replace the standards, but rather to present guidelines for the development of items and item clusters used to measure those standards.

The remainder of this section provides a very brief introduction to the standards and the framework, an overview of the design and intent of the item clusters, and a description of the cluster specifications that follow. The bulk of the document is composed of cluster specifications, organized by grade and standard.

Background on the framework and standards

The Framework for K-12 Science Education are organized around three core dimensions of scientific understanding. The standards are derived from these same dimensions:

- Disciplinary Core Ideas: The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.

- Science and Engineering Practices: The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

- Cross-Cutting Concepts: These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.

- There is substantial overlap between and among the three dimensions. For example, the cross-cutting concepts are echoed in many of the disciplinary core ideas. The core ideas are often closely intertwined with the practices. This overlap reflects the nature of science itself. For example, we often come to understand and communicate causal relationships by employing models to make sense of observations. Even within a dimension, overlap exists. Quantifying characteristics of phenomena is important in developing an understanding of them, so employing computational and mathematical thinking in the construction and use of models is a very common scientific practice, and one of the cross-cutting concepts suggests that scientists often infer causality by observing patterns. In short, the dimensions are not orthogonal.

The framework envisions effective science education as occurring at the intersection of these interwoven dimensions: students learn science by doing science—applying the practices through the lens of the cross-cutting concepts to investigate phenomena that relate to the content of the disciplinary core ideas.

Item clusters

Each item cluster is designed to engage the examinee in a grade-appropriate, meaningful scientific activity aligned to a specific standard.

Each cluster begins with a phenomenon, an observable fact or design problem that engages student interest and can be explained, modeled, investigated, or designed using the knowledge and skill described by the standard in question.

What it means to be observable varies across practices. For example, a phenomenon for a performance expectation exercising the a*nalyze data* practice may be observable through regularities in a data set, while standards related to the *development and use of models* might be something that can be watched, seen, felt, smelled, or heard.

What it means to be observable also varies across grade levels. For example, elementary-level phenomena are very concrete and directly observable. At the high school level, an observation of the natural world may be more abstract--for example, "observing" changes in the chemical composition of cells through the observation of macroscopic results of those changes on organism physiology, or through the measurement of system- or organ-level indications.
Content limits refine the intent of the performance expectations and provide limits on what may be asked of items in the cluster to structure the student activity. The content limits also reflect the disciplinary core ideas learning progressions that are present in the K-12 Framework for Science Education.

The task or goal should be explicitly stated in the stimulus or the first item in the cluster: statements such as "In the questions that follow, you will develop a model that will allow you to identify moons of Jupiter," or "In the questions below, you will complete a model to describe the processes that lead to the steam coming out of the teapot."
Whereas item clusters have been described elsewhere as "scaffolded," they are better described as providing structure to the task. For example, some clusters begin with students summarizing data to discover patterns that may have explanatory value. Depending on the grade level and nature of the standard, items may provide complete table shells or labeled graphs to be drawn, or may require the student to choose what to tabulate or graph. Subsequent items may ask the student to note patterns in the tabulated or graphed data and draw on domain content knowledge to posit explanations for the patterns.
These guidelines for clusters do not appear separately in the specifications. Rather, they apply to all clusters.

Structure of the cluster specifications

The item cluster specifications are designed to guide the work of item writers and the review of item clusters by stakeholders.
Each item cluster has the following elements:

- The text of the performance expectations, including the practice, core idea, and cross-cutting concept.
- Content limits, which refine the intent of the performance expectations and provide limits of what may be asked of examinees. For example, they may identify the specific formulae that students are expected to know or not know.
- Vocabulary, which identifies the relevant technical words that students are expected to know, and related words that they are explicitly not expected to know. The vocabulary included in both sections (Students are Expected to Know and Students Are Not Expected to Know) were developed after the reviews of standards at the current/preceding grades, the original NGSS documentation, and item writer reference documentation including the Children Writers' Word Book and ED Core Vocabularies in Reading, Mathematics, Science and Social Studies. All vocabulary included in the specifications was reviewed and edited by teacher committees during the specification reviews by states. Of course, the latter category should not be considered exhaustive, since the boundaries of relevance are ambiguous, and the list is limited by the imagination of the writers/reviewers.
- Sample phenomena, which provide some examples of the sort of phenomena that would support effective item clusters related to the standard in question. In general, these should be guideposts, and item writers should seek comparable phenomena, rather than drawing on those within the documents. Novelty is valued when applying scientific practices.
- Task demands comprise the heart of the specifications. These statements identify the types of items and activities that item writers should use, and each item written should be clearly linked to one or more of the demands. The verbs in the demands (e.g., *select, identify, illustrate, describe*) provide guidance on the types of interactions that item writers might employ to elicit the student response. We avoid explicitly identifying interaction types or item formats to accommodate future innovations and to avoid discouraging imaginative work by the item writers. All task demands should be aligned to a minimum of one of the three dimensions (DCI, SEP and CCCs) and across task demands within a cluster, all three dimensions must be addressed.

- For each cluster we present, the printed documentation includes the cluster, the task demands represented by each item, and its linkage to the content, practice and cross-cutting concept identified in the performance expectation.

Item cluster specifications follow, organized by domain and standard.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS1-1
Develop models to describe the atomic composition of simple molecules and extended structures.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and/or use a model to predict and/or describe phenomena.</td><td>PS1.A: Structure and Properties of Matter
• Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
• Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).</td><td>Scale, Proportion, and Quantity
• Time, space, and energy phenomena can be observed at various scales, using models to study systems that are too large or too small.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on identifying elements vs. compounds and their basic units of atoms and molecules.
• Emphasis is on developing models of molecules that vary in complexity.
• Examples of simple molecules could include ammonia, methanol, methane, water, carbon dioxide, etc.
• Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.
• Examples of extended structures could include sodium chloride or diamonds.

Content Limits
• Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.
• Modelling should be limited to molecules that have only one type of bond, no combination of bonds; the structure of the molecule is easy to model; single bonded molecules.
• Students are not expected to memorize the atomic characteristics of any element.
• <u>Students do not need to know</u>: valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, a complete description of all individual atoms in a complex molecule or extended structure, memorization of atoms found in different molecule, VSEPR or geometric arrangements, the difference between single, double, and triple bonding, periodic table patterns and how it affects bonding, oxidation numbers, polyatomic ions.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Element, compound, mixtures, homogenous, heterogeneous, pure substances, solution, solvent, solute.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Valence electrons, subatomic particles such as protons, electrons, neutrons, neutrinos etc., ions, positive or negative charges, covalent bond, ionic bond.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS1-1:</td></tr>
</table>

	• Submarines can stay underwater for months using sea water as a source of oxygen for air. Special machines run electricity through large amounts of sea water, generating oxygen from the water. • Water and hydrogen peroxide are both made up of hydrogen and oxygen. When water is poured on a chunk of $CaCO_3$, there is no reaction. When hydrogen peroxide is poured on a chunk of $CaCO_3$, it fizzes. • Oxygen (O_2) is a gas we breathe to stay alive. Ozone (O_3), also made only of oxygen atoms, is unhealthy to breathe.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify or assemble from a collection of potential model components, including distractors, components of a model that describes the structures of atoms, molecules, or extended molecules and/or how they interact, or explains how atoms of the same or different element(s) are arranged in repeated patterns in extended structures.
2. Describe, select, and/or identify the relationships among components of a model that describes the structures of atoms, molecules, or extended molecules and/or how they interact, or explains how atoms of the same or different element(s) are arranged in repeated patterns in extended structures.
3. Assemble, illustrate, describe, and/or complete a model or manipulate components of a model to describe the structure of an atom, molecule, or extended molecule and/or how they interact, or to explain or predict how atoms of the same or different element(s) are arranged in repeated patterns in extended structures.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS1-2
Analyze and interpret data on the properties of substances before and after the substances interact to determine whether a chemical reaction has occurred.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to determine similarities and differences in findings.</td><td>PS1.A: Structure and Properties of Matter
• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B: Chemical Reactions
• Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.</td><td>Patterns
• Macroscopic patterns are related to the nature of microscopic and atomic-level structure.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.

Content Limits
• Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.
• Students are not expected to balance chemical equations or to determine whether a chemical equation is balanced or not.
• Students are expected to know that mass/matter is neither destroyed nor created.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Reactant, product, compound, matter, mass, volume, density, melting point, boiling point, freezing point, solubility, dissolve, flammability, odor, gas, solid, liquid, chemical bonds.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Collision theory, oxidation, reduction, intramolecular attractions, intermolecular attractions, solvent, solute, precipitant, limiting reactant, excess reactant, covalent bond, ionic bond, rate of reaction, acid, base, salt (as an ionic crystal), fusion, fission, homogeneous mixture, heterogeneous mixture.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation the phenomena are mixtures of substances that provide sets of data. Those are the observations and/or measurements concerning the physical and chemical properties of the involved substances before and after mixing that the kids will look at to discover patterns. Below, we enumerate some of the mixtures that might provide the data sets to be analyzed.

All phenomenon for this PE should be situations where a chemical reaction is not immediately apparent.

Some example phenomena for MS-PS1-2:
• Rainwater can produce stains on car paint. Reports of these stains are more common in the Southeastern U.S. than they are in the Midwest.</td></tr>
</table>

	• Portions of marble statues that are exposed to rainwater crack and crumble over time. Portions of marble statues that are sheltered develop a black coating over time. • When sugar crystals are added to vinegar in a bowl, the crystals disappear. When crystals of table salt are added to vinegar in a bowl, the mixture begins to bubble and foam. • Table sugar exposed to an open flame transforms into a gooey, dark substance. Wood exposed to an open flame transforms into ash.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize, arrange, and/or generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations among observations and data concerning the physical and chemical properties of the substances involved. This may include sorting out distractors.
2. Describe and/or summarize data (e.g., using illustrations and/or labels), to identify/highlight trends, patterns, or correlations among observations and data concerning the physical and chemical properties of the beginning and ending substances being investigated.*
3. Use relationships identified in the data to predict whether the mixing of substances similar to the ones under study will result in the occurrence of a chemical reaction.
4. Identify patterns or evidence in the data that support inferences about any changes that occurred in the microscopic or atomic-level arrangements of the substances involved.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS1-3
Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.</td><td>PS1.A: Structure and Properties of Matter
• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B: Chemical Reactions
• Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.</td><td>Structure and Function
• Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on natural resources that undergo a chemical process to form the synthetic material.
• Examples of new materials could include new medicine, foods, building materials, plastics and alternative fuels

Content Limits
• Assessment is limited to qualitative information.
• Students are not required to know particular names for synthetic materials (i.e. rayon, polyester, acrylic, nylon, rayon, acetate, orlon, Kevlar)
• <u>Students do not need to know</u>: the types of reaction mechanisms involved in chemical reactions such as polymerization.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Atom, molecule, pure substance, subunit, molecular arrangement, matter, particle, pressure, conductivity, reactant, dissolve, mineral, conductive, separation method (for mixtures), sodium chloride, carbon dioxide, negative impact, petroleum, natural gas, oil</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Acid, base, reversible reactions, irreversible reactions, condensation reaction, polymer, polymerization, bond, electron configuration, chromatography, catalyst, electron transfer, graphite, pharmaceutical, synthetic polymer, harvesting of resources, oil shale, geopolitical, extract, cost-benefit, organic materials</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS1-3:
• It is difficult for the naked eye to tell the difference between cubic zirconia (CZ) and diamond, but a genuine diamond will give off a strong blue fluorescence when held under U.V. light.
• Naturally occurring penicillin from penicillium mold is an effective antibiotic against infections, but it is broken up by stomach acid and can only be injected into the bloodstream.
• The bark of the white willow tree can be used as an alternative to aspirin for pain relief.</td></tr>
</table>

	• Nylon and Kevlar are both synthetic fabrics, but Kevlar is much stronger – about five times as strong as steel.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols and mathematical representations to describe how synthetic materials are made and how they come from natural resources.*
2. Based on the information provided, identify, describe or illustrate a claim regarding the relationship between a characteristic of a synthetic material and its function in real world applications.
3. Identify, summarize, or organize given data or other information to support or refute a claim that relates characteristic of a synthetic material to its function in real world.
4. Identify relationships or patterns in scientific evidence at macroscopic and/or microscopic scales.
5. Synthesize an explanation that incorporates the scientific evidence from multiple sources.
6. Using scientific evidence, evaluate the validity/relevance/reliability of using synthetic materials as alternatives to natural materials and/or their impact on society.

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**For stand-alone items, focus on charts, diagrams, etc. rather than text-heavy stems for time considerations.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS1-4
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model to predict and/or describe phenomena.</td><td>PS1.A: Structure and Properties of Matter
• Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
• In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
• The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS3.A: Definitions of Energy
• The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary)
• The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material (secondary).</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs.
• Examples of models could include drawings and diagrams.
• Examples of particles could include molecules of inert atoms.
• Examples of pure substances could include water, carbon dioxide, and helium.

Content Limits:
• Physical changes should be limited to freezing, melting, condensation, and evaporation.
• Assessment does not include:
o Sublimation (solid change of state directly to a gas);
o Calculations for internal energy, transfer of heat (q), (system and surroundings), entropy, work, and Hess’s law;
o Ideal gas laws and their relationships (Boyle’s, Charles, Combined, PV=nRT, etc.);
o The role that pressure and force (N) have in the kinetic molecular theory;
o Energy needed to break and reform chemical bonds in a chemical reaction, including the use of a catalyst to speed up a reaction;
o Absolute zero and kelvin (Celsius and Fahrenheit temperature only).</td></tr>
</table>

	• Students do not need to know: o Atomic structure (electrons orbit around a nucleus containing protons and neutrons) o The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. o Stable forms of matter are those in which the electric and magnetic field energy is minimized. o A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to break the bonds of a molecule. o 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 among its various possible forms.
Science Vocabulary Students are Expected to Know	Phase, phase change, thermal energy, kinetic energy, pure substance, compound, thermometer, matter, melting, freezing, condensation, vapor, heat, vibrate, collide, inert atom.
Science Vocabulary Students are Not Expected to Know	Entropy, enthalpy, ideal gas law, sublimation, plasma, triple point, critical point, proton, neutron, electron, valence electrons, electrical energy, bond energy.
Phenomena	
Context/ Phenomena	Some example phenomena for MS-PS1-4: • A tea kettle is sitting on a stove, under heat. As the water in the kettle begins to boil, a stream of steam is visible outside of its spout. • Dew forms on the grass in the morning. • As sugar is heated in a pan, it turns from a white solid to a light brown liquid.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components, including distractors, the components needed to model of the model changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. Components might include: energy source, particles in motion, and boundaries of system.	
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. This does not include labeling an existing diagram.	
3. Manipulate the components of the model to demonstrate the changes, properties, processes, and/or events that act to result in the changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.*	
4. Make predictions about the effects of changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.*	
5. Given models or diagrams of particle motion, temperature, and state of a pure substance when thermal energy is added or removed, identify how they change over time in a given scenario OR identify the properties of the variables that cause the changes.	

6. Identify missing components, relationships or other limitations of the model.
7. Describe, select, or identify the relationships among components of a model that describe changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD4 must be used with TD3 (…by completing illustrations…etc. is what makes this need to be paired)

Performance Expectation	**MS-PS1-5** Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.		
Dimensions	**Developing and Using Models** • Develop and use a model to describe unobservable mechanisms.	**PS1.B: Chemical Reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. • The total number of each type of atoms is conserved and thus the mass does not change.	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.
Clarifications and Content Limits	**Clarification Statements** • Emphasize demonstrations of an understanding of the law of conservation of matter. • Emphasis is on law of conservation of matter and on physical models or drawings, including digital formats that represent atoms. • Models can include already balanced chemical equations. **Content Limits** • Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces. • Assessment does not include stoichiometry or balancing equations. • Assessment is limited to simpler molecules, i.e., carbon dioxide, ammonia, sodium chloride, methanol, calcium chloride.		
Science Vocabulary Students Are Expected to Know	Transfer, molecule, element, conversion, phase change, dissolve, reactant, product.		
Science Vocabulary Students Are Not Expected to Know	Acid-base reactions, base, catalyst, reaction rate, endothermic/exothermic, equilibrium, oxidation-reduction reaction, chemical bond, electron sharing, electron transfer, ion, isotope.		
Phenomena			
Context/ Phenomena	Some example phenomena for MS-PS1-5: • An antacid tablet was added to water and bubbles appeared. The mass of the water and antacid tablet after the tablet dissolved was less than the mass of the water and tablet before they were mixed. • A strip of metal was added to acid in a test tube and a balloon was placed on top of the test tube. Bubbles appeared and after a few minutes, the balloon inflated.		

	• 100g of sugar completely dissolved in 100ml of water. After it dissolved, the mass of the mixture was 200g. • Steel wool was soaked in water ad left out to dry. The steel wool turned dark red, ad the mass of the steel wool after it dried was greater than before it was soaked in the water.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
7. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include atoms and molecules.	
8. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing the conservation of matter.*	
9. Manipulate the components of the model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.*	
10. Make predictions about the effects of changes in chemical reactions. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.**	
11. Identify missing components, relationships, or limitations of the model.	
12. Describe, select, or identify the relationships among components of a model that describe the conservation of matter, or explain the chemical reaction.	
13. Use the model to provide a causal account that matter is conserved during a chemical reaction by calculating the number of atoms or total mass of reactants and products.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD4 may only be used in conjunction TD3

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS1-6
Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.</td><td>PS1.B: Chemical Reactions
• Some chemical reactions release energy, others store energy

ETS1.B: Developing Possible Solutions
• A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (secondary)

ETS1.C: Optimizing the Design Solution
• Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design. (secondary)
• The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (secondary)</td><td>Energy and Matter
• The transfer of energy can be tracked as energy flows through a designed or natural system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance.
• Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.

Content Limits
• Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.
• <u>Students do not need to know:</u>
    • Types of chemical reactions (decomposition, synthesis, single replacement, double replacement, combustion, etc.)
    • How to balance a chemical equation</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Reactant, product, chemical bond, compound, molecule, solution, dissolve, solubility, concentration, chemical potential energy, thermal energy, system, environment, evaporate, condense</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Endothermic, exothermic, precipitant, solute, solvent, crystallization, dissolution, polar/polarity, ion, intermolecular force, intramolecular force, enthalpy, entropy, heat of solution, heat of reaction, microstates, equilibrium, saturate/saturation</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
</table>

<table>
<tr><td>Context/
Phenomena</td><td>Engineering performance expecations are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

Some example design problems for MS-PS1-6:
Design a sport’s injury pack that when used, will heat and soothe sore muscles.
Design a sport’s injury cold pack that will help prevent swelling.
Design a self-heating pad that can warm ready-to-eat meals.
Design a device that can be used to keep electronics, like computers, from overheating.</td></tr>
<tr><td colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2">Task Demands</td></tr>
<tr><td colspan="2">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="2">2. Express or complete a causal chain explaining the chemical processes that resulted in the release or absorption of thermal energy. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.</td></tr>
<tr><td colspan="2">3. Describe, identify, and/or select evidence supporting the inference of causation that is expressed in a causal chain and/or an explanation of the processes that cause the observed results.</td></tr>
<tr><td colspan="2">4. Use an explanation to predict the direction or the relative magnitude of a change in thermal energy of a chemical system, given a change in the amount/concentration of chemical substances in the system, the temperature of the substances in the system, and/or the amount of time the substances interact in the system.</td></tr>
<tr><td colspan="2">5. Identify or assemble from a collection, including distractors, the relevant aspects of the problem that given design solutions, if implemented, will resolve/improve.</td></tr>
<tr><td colspan="2">6. Using the given information, select or identify the criteria against which the device or solution should be judged.</td></tr>
<tr><td colspan="2">7. Using given data, propose, illustrate, or assemble a potential device (prototype) or solution.</td></tr>
<tr><td colspan="2">8. Using a simulator, test a proposed prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS2-1
Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific ideas or principles to design an object, tool, process, or system.</td><td>PS2.A: Forces and Motion
• For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s Third Law).</td><td>Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.

Content Limits
• Assessment is limited to vertical or horizontal interactions in one dimension.
• <u>Students do not need to know</u>: vector addition</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Conservation of momentum, energy transfer, transfer, force, balanced force, friction, direction of a force, impact, net force, inertia, action/reaction, gravity, acceleration, Newton, thrust, lift.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Elastic collision, inelastic collision, impulse, coefficient of restitution, drag force, terminal velocity, friction coefficient, horizontal and vertical velocities (arc), aerodynamics, magnitude, vector.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering performance expectations are built around meaningful design problems rather than phenomena. In this case, the design problems involve two colliding objects in a system. For this performance expectation, the design problem and competing solutions replace phenomena.

Some example design problems for MS-PS2-1:
• Testing different balls/objects for elementary students to throw at a dunk-tank target.
• Design a bike helmet that will keep the rider safe during a collision.
• Design a container that will protect vaccines from breaking as they are transported across rough terrain.
• Use Newton’s third law to create a system that will allow a ball to bounce higher than the height from which it was dropped.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify or assemble from a collection, including distractors, the relevant aspects of the problem that given design solutions, if implemented, will resolve/improve.</td></tr>
<tr><td colspan="4">2. Using given information, select or identify constraints that the device or solution must meet, including cost, mass, and speed of objects and materials.</td></tr>
</table>

3. Using the given information, select or identify the criteria against which the device or solution should be judged.
4. Using given data, propose/illustrate/assemble a potential device (prototype) or solution.*
5. Using a simulator, test a proposed prototype and evaluate the outcomes; potentially propose and test modifications to the prototype.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS2-2
Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim</td><td>PS2.A: Forces and Motion
• The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
• All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.</td><td>Stability and Change
• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on:
  • Balanced (Newton’s First law) and unbalanced forces in a system
  • Qualitative comparisons of forces, masses and changes in motion (Newton’s Second Law)
  • Frame of reference and specification of units

Content Limits
• Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time.
• <u>Students do not need to know:</u> trigonometry</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Applied force, balanced force, collision, force, unbalanced force, position over time, net force</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Newton’s Laws of Motion, acceleration, velocity, inertial frame of reference, momentum, friction</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS2-2:
• A tennis ball is dropped on a trampoline and bounces up to a height, h. A bowling ball is then dropped on the same trampoline. The bowling ball bounces up to a height higher than h.
• A bowling ball is rolled towards a bowling pin. When the bowling ball hits the pin, the pin falls down. Then, a marble is rolled towards a bowling pin. When the marble hits the pin, the pin does not fall down.</td></tr>
</table>

	• A soccer player kicks the ball 50 yards. She then kicks another ball and it only goes 30 yards. • Two magnets of the same size are held apart from each other. One magnet is let go and moves towards the stationary magnet. When two other magnets are close to each other and one is let go, it moves toward the stationary magnet, faster.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify from a list, including distractors, the materials/tools needed for an investigation of how the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
2. Identify the outcome data that should be collected in an investigation of how the sum of the forces on an object, as well as the object's mass, affect the change in motion of the object.
3. Evaluate the sufficiency and limitations of data collected to explain the phenomenon.
4. Make and/or record observations about how the sum of the forces on an object, and the mass of the object, affect the change in motion of the object.
5. Interpret and/or communicate the data from an investigation on how the change in motion of an object is affected by the sum of all forces and the mass of the object.
6. Explain or describe the causal processes that lead to the data that is observed in an investigation of how the forces on an object, and its mass, affect its change in motion.
7. Select, describe, or illustrate a prediction made by applying the findings from an investigation on how the forces on an object, and its mass, affect its change in motion.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS2-3
Ask questions about data to determine the factors that affect the strength of electrical and magnetic forces.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.</td><td>PS2.B: Types of Interactions
• Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples could include electromagnets, electric motors, or generators.
• Examples of data could include the effect of the number or turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

Content Limits
• Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Attraction, conductor, electric current, electric field, electromagnetic field, electromagnet, frequency, induction, insulator, permanent magnet, polarity, repulsion, resistance, voltage.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Lorentz force, electric potential, electromotive force.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS2-3:
• A radio emits music from its speakers. After a magnet in the speakers is removed, no sound can be heard.
• More electrical current is produced by a windmill when the wind speed is greater.
• Merchandise from a store that uses electromagnetic anti-shoplifting devices will set off an alarm at the exit if the tag is not removed.
• An electromagnet at a junkyard can lift old cars, while a homemade electromagnet cannot pick up much more than a few paper clips.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Make and/or record observations about the factors that affect electromagnets, electric motors, or generators.</td></tr>
<tr><td colspan="4">2. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in the change in the strength of electrical and magnetic forces.</td></tr>
</table>

3. Generate or construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in the factors that affect the strength of electric and magnetic forces. This may include sorting out distractors.
4. Explain or describe the causal processes that lead to the change in the strength of electrical and magnetic forces.
5. Use relationships identified in the data to predict the strength of electric and/or magnetic forces.
6. Select from a list of questions, including distractors, a scientifically testable question about factors that affect the strength of electrical or magnetic forces.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS2-4
Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.</td><td>PS2.B Types of Interactions
• Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.</td><td>Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of evidence of arguments could include data generated from simulations or digital tools, and charts displaying mass, strength of interaction, distance from the sun, and orbital periods of objects within the solar system.

Content Limits
• Assessment does not include Newton’s law of gravitation or Kepler’s laws.
• <u>Students do not need to know:</u> mathematical representations of gravity (values, units, etc.).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Orbit, magnitude, galaxy, solar system, satellite, force fields, ellipse, proportional, period.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Terminal velocity, relativity, gravitational energy, gravitational field, inverse square law.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS2-4:
• The moon orbits Earth.
• Astronauts fall more slowly when jumping on the moon than on Earth.
• A dropped apple falls toward Earth, but not toward the moon.
• Rockets have to travel extremely fast when they leave Earth.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information.</td></tr>
<tr><td colspan="4">2. Predict outcomes when properties or proximity of the objects are changed, given the inferred cause and effect relationships</td></tr>
<tr><td colspan="4">3. Describe, identify, and/or select information needed to support an explanation.**</td></tr>
</table>

4. Identify patterns or evidence in the data that support conclusions about the relationship between mass and gravity.*
5. Using evidence, explain the relationship between mass and gravity.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD3 may be used only in conjunction with TD4 or TD5.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS2-5
Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.</td><td>PS2.B: Types of Interactions
• Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls.
• Examples of investigations could include first-hand experiences or simulations.

Content Limits
• Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Conductor, electric charge, electric current, electric force, electromagnetic field, electromagnet, frequency, induction, insulator, magnetic field lines, magnetic force, permanent magnet, polarity, repulsion, resistance, voltage, direction, magnitude, ampere, charged particle, volts, gravity</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Lorentz force, electric potential, electromotive force, permeating, vector field, quantum property, Laplace force, Right-hand rule, Ampere’s Law, electrodynamics, magnetic dipole, Coulomb force, electrostatic, general relativity</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS2-5:
• A compass is opened and set on a table. The needle spins for a bit and then settles pointing north.
• Two blue-painted metal boxes sit on a table. With a pocket knife, a person easily scratches some of the paint off of one box. But they cannot remove the paint from the other box.
• A person walks across a carpeted floor in stocking feet. They touch another person who is sitting in a chair, delivering a large shock.
• A multimeter records the presence of an electric current when a coil rotates near a magnet.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify from a list, including distractors, the materials/tools/steps needed for an investigation of fields that exist between objects exerting forces on each other even though the objects are not in contact.</td></tr>
<tr><td colspan="4">2. Identify the outcome data that should be collected for a given purpose in an investigation of fields that exist between objects exerting forces on each other even though the objects are not in contact.</td></tr>
</table>

3. Evaluate the sufficiency and limitations of data collected to explain the phenomenon.
4. Make and/or record observations about fields that exist between objects exerting forces on each other even though the objects are not in contact.
5. Interpret and/or communicate the data from an investigation of the field that exists between two objects exerting forces on each other even though the objects are not in contact.
6. Explain, describe, or identify the causal processes that lead to the observed data about the field that exists between two objects exerting forces on each other even though the objects are not in contact.
7. Select, describe, or illustrate a prediction made by applying the findings from an investigation of the field that exists between two objects exerting forces on each other even though the objects are not in contact

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS3-1
Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Construct and interpret graphical displays of data to identify linear and nonlinear relationships</td><td>PS3.A: Definitions of Energy
• Motion energy is properly called kinetic energy it is proportional to the mass of the moving object and grows with the square of its speed.</td><td>Scale, Proportion, and Quantity
• Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed.
Examples could include:
Riding a bicycle at different speeds
Rolling different sizes of rocks downhill
Getting hit by a wiffle ball vs a tennis ball
Content Limits
<u>Students do not need to know:</u> vectors such as velocity, the exact formula for the kinetic energy of an object or how to make calculations using the formula.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Forms of energy, magnitude, motion energy, proportional, ratio, square root, potential energy, elastic collision, inelastic collision</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Velocity, vector, inertial frame of reference, acceleration, deceleration, relative motion, Newtonian Mechanics</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS3-1:
Balls of different masses are dropped into a pile of snow. A graph of the mass vs. the depth of the indent is shown.
A pendulum is dropped so that it hits a box on the ground. A graph of the drop height vs the distance the box travels is shown.
A ball thrown at a wall will bounce back a certain distance. A table of the speed of the ball vs. the distance it bounces back is given.
Trains with differing amounts of train cars all come to a stop. A table of the number of train cars vs stopping distance is given.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations among observations and data concerning the mass, speed and kinetic energy of objects. This may include sorting out distractors.</td></tr>
</table>

2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in how the kinetic energy of an object changes with its mass and its speed. This may include sorting out distractors.
3. Use relationships identified in the data to predict how the kinetic energy of an object will change based on a change in speed of the object or mass of the object.
4. Identify patterns or evidence in the data that supports inferences about how kinetic energy changes with the speed of an object and the mass of an object.

Performance Expectation	**MS-PS3-2** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.		
Dimensions	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**PS3.A: Definitions of Energy** • A system of objects may also contain stored (potential) energy, depending on their relative positions. **PS3.C: Relationship Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on relative amounts of potential energy, not on calculations of potential energy. • Examples of objects within systems interacting at varying distances could include the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. • Examples of models could include representations, diagrams, pictures, and written descriptions of systems. **Content Limits** • Assessment does not include calculations of kinetic and potential energy. • Assessment is limited to two objects and electric, magnetic, and gravitational interactions.		
Science Vocabulary Students are Expected to Know	Electron, proton, distribution of charged particles, electrical charge, negatively charged, positively charged, neutrally charged, magnetic polarity, conductor, insulator, electromagnet.		
Science Vocabulary Students are Not Expected to Know	Oscillation, harmonic oscillator, period, momentum, spring constant, equilibrium position, acceleration of gravity, work, power, mechanical advantage, Work-energy theorem, rotational motion, translational motion, torque, moment, Coulomb's law, Faraday cage, triboelectricity, electric potential, gravitational potential.		
Phenomena			
Context/ Phenomena	Some example phenomena for MS-PS3-2: • A roller coaster track contains two hills of equal size. A roller coaster car sitting on the first hill is released and allowed to roll down the tracks of the first hill. The car comes to a stop before it reaches the top of the second hill. • Two wrecking ball cranes sit next to two concrete buildings. Crane A has a ball that has less mass than the ball of Crane B. Both cranes swing their balls toward the buildings. Crane A's ball starts out higher than Crane B's ball. Crane A's ball does substantially more damage to the building than Crane B's ball. • The poles of an electromagnet can be reversed by reversing the electromagnet's connection to a battery. • An empty shopping cart rolls down a hill in a parking lot and dents a parked car, while a full shopping cart rolls across a flat lot and does not damage a parked car.		

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components, including distractors, the components needed to model different amounts of potential energy stored in a system, compared to the distance between interacting objects. Components might include: energy source, objects in motion, and boundaries of system.	
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing changes in potential energy stored in a system. This *does not* include labeling an existing diagram.	
3. Manipulate the components of the model to demonstrate the changes, properties, processes, and/or events that act to result in the changes in potential energy.	
4. Make predictions about the effects of changes in distances between interacting objects and the potential energy stored in the system. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.	
5. Given models or diagrams of a system containing potential energy, identify how the energy changes over time in a given scenario OR identify the properties of the variables that cause the changes.	
6. Identify missing components, relationships, or other limitations of the model.	
7. Describe, select, or identify the relationships among components of a model that describe changes in potential energy of a system when the distance between interacting objects changes.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS PS3-3
Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.</td><td>PS3.A: Definitions of Energy
• Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy
• Energy is spontaneously transferred out of hotter regions or objects and into colder ones

ETS1.A: Defining and Delimiting an Engineering Problem
• The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.

ETS1.B: Developing Possible Solutions
• A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.</td><td>Energy and Matter
• The transfer of energy can be tracked as energy flows through a designed or natural system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Examples of devices could include an insulated box and a Styrofoam cup.

Content Limits
• Students should be given the problem to solve.
• <u>Students do not need to know</u>: Calculate energy of the system or change in energy.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Temperature, kinetic energy, energy transfer, conductor, insulator, convection conduction and radiation.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Energy units (joules, amperes), charged particles</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering performance expectations are built around meaningful design problems rather than phenomena. For this performance expectation, design problems or design solutions replace phenomena.

Some examples of design problems for MS-PS3-3:
• A heated swimming pool needs to be covered to reduce energy costs in the winter.</td></tr>
</table>

	• Many cooks prefer pans that heat more evenly. Which materials should pans be made of? • Design a more energy-efficient window. • Choose the materials for a pot holder.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify or assemble from a collection the relevant aspects of the problem that given design solutions for either minimizing or maximizing thermal energy transfer, if implemented, will resolve/improve.
2. Using the given information, select or identify the criteria against which the device or solution that either minimizes or maximizes thermal energy transfer should be judged.
3. Using given information, select or identify constraints that the device or solution that either minimizes or maximizes thermal energy transfer must meet.
4. Using given data, propose, illustrate, and/or assemble a potential device (prototype) or solution that either minimizes or maximizes thermal energy transfer.
5. Using a simulator, test a proposed prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS3-4
Plan an investigation to determine the relationships among energy transferred, type of matter, mass, and change in the average kinetic energy of particles, as measured by the temperature of a sample.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan an investigation individually and collaboratively and, in the design, identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.</td><td>PS3.A: Definitions of Energy
• Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer
• The amount of energy transfer needed to change the temperature of a sample of matter by a given amount depends on the nature of the matter, the size of the sample, and the environment.</td><td>Scale, Proportion, and Quantity
• Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature; the temperature change of samples of different materials with the same mass as they cool or heat in the environment; or the same material with different masses when a specific amount of energy is added.

Content Limits
• Assessment does not include calculating the total amount of thermal energy transferred.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Volume, collide, collision, heat conduction, particle, stored energy, transfer, average, proportional, ratio, thermal energy</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Thermal equilibrium, thermodynamics</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS3-4:
• A mug of hot coffee is set on a cork coaster. After letting the mug of coffee sit for a while, a person picks up the mug and the coaster and notices that both the mug and coaster are warm.
• When placed over the same heat source, water takes longer to reach 100C^{o} than a cola soft drink.
• Pot holders work well when they’re dry. When they’re wet, they don’t.
• A metal spoon used to stir a hot beverage gets hot much more quickly than a wooden spoon.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Identify from a list, including distractors, the materials/tools needed for an investigation of how thermal energy is transferred to and from the environment and to and from materials of different/ same types of matter and different/ same masses.
2. Identify the data that should be collected in an investigation of how thermal energy is transferred to and from the environment and to and from materials of different/ same types of matter and different/ same masses.
3. Evaluate the sufficiency and limitations of data collected to explain a phenomenon.
4. Make and/or record observations about time, mass of materials, type of materials, initial and final average kinetic energy (temperature) of materials, and the surrounding environment.
5. Interpret and/or communicate data from an investigation.
6. Explain or describe the causal processes that lead to observed data.
7. Select, describe, or illustrate a prediction made by applying the findings from an investigation.
8. Assemble or specify a controlled experiment or investigation to evaluate the effect of the type of matter, amount of heat, or volume of material heated.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS3-5
Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.</td><td>PS3.B: Conservation of Energy and Energy Transfer
• When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.</td><td>Energy and Matter
• Energy may take different forms (e.g., energy in fields, thermal energy, and energy of motion).</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on understanding that when the kinetic energy of an object increases or decreases, the energy (e.g., kinetic, thermal, potential, light, sound) of other objects or the surroundings within the system increases or decreases, indicating that energy was transferred to or from the object.
• Emphasis is on knowing that temperature is the measure of the average kinetic energy of particles of matter.
• Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of an object.

Content Limits
• Assessment does not include any calculations of energy or energy flow.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Potential energy, heat energy, closed system, open system, friction, joule, force, transformation of energy, thermometer, Fahrenheit, Celsius, pendulum, sound energy, conservation of energy</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Co-efficient of kinetic energy, air resistance, work, energy efficiency, chemical energy, electrical energy, machine (for transforming energy), mechanical energy.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS3-5:
• The Riverside geyser in the Upper Geyser Basin at Yellowstone National Park throws out jets of hot water into the air at regular intervals.
• When the brakes are applied, sparks fly out between the wheels and the metal tracks as a train slows down.
• Bowling pins fall over and start to roll when struck by a bowling ball.
• A hot air balloon lifts off the ground as the burner is lit under the balloon.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information.</td></tr>
</table>

2. Predict outcomes when the kinetic energy of an object changes, given the inferred cause and effect relationships.
3. Describe, identify, and/or select information needed to support an explanation of a change in kinetic energy or energy transfer.
4. Identify patterns or evidence in the data that support the claim that the kinetic energy of an object changes as energy is transferred to or from the object.
5. Using evidence, explain the relationship between the kinetic energy of an object and changes to the object or the surroundings, as energy is transferred to or from the object.
6. Manipulate the components of a model to demonstrate that the kinetic energy of an object changes as energy is transferred to or from the object.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS4-1
Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations to describe and/or support scientific conclusions and design solutions.</td><td>PS4.A: Wave Properties
• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.</td><td>Patterns
• Graphs and charts can be used to identify patterns in data.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasize describing waves with both quantitative and qualitative thinking.
• Examples could include using graphs, charts, computer simulations, or physical models to demonstrate amplitude and energy correlation.
• All equations and formulas must be provided and be age-appropriate.

Content Limits
• Assessment does not include electromagnetic waves and is limited to standard repeating waves.
• Assessment does not include identifying or knowing characteristics of different types of waves (mechanical, electromagnetic, sonic, etc.).
• <u>Students do not need to know</u>: how two waves carrying the same energy can have different amplitudes when introduced into materials of different densities and elasticities.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Speed, force, kinetic energy, proportional, sound wave, wavelength, frequency, resting position, medium, crest, trough</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Elastic, seismic wave, oscillate.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS4-1:
• The 1896 Sanriku earthquake off the coast of Japan generated ocean waves that reached a height of 100 feet (30 m).
• Compared to a megaphone that sends sound messages up to 300 meters away, a Long Range Acoustic Device (LRAD) sends messages that can be heard up to 5,500 meters away.
• Scientists at the Swiss Federal Institute in Zurich caused a toothpick to levitate using sound waves.
• A wave travels down a rope from one student to another when the first student shakes it.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Compile and analyze data to make an inference about the relationship between amplitude and energy of a wave. This may include sorting out relevant from irrelevant data in the given information.</td></tr>
<tr><td colspan="4">2. Organize and/or arrange (e.g., using illustrations and/or labels) or summarize data to highlight trends, patterns, or correlations that reflect how energy changes with amplitude of a wave and vice versa.</td></tr>
</table>

3. Identify how wave characteristics correspond to physical observations (e.g., wave amplitude corresponds to sound volume).
4. Use relationships identified in the data to predict the energy or amplitude change of a wave if the other parameter is changed.
5. Based on data, calculate or estimate one property of a wave (energy or amplitude) and the relationships between different properties of a wave.
6. Use graphs, charts, simulations, or physical models to demonstrate amplitude and energy correlation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS4-2
Develop and/or use a model to describe that waves are reflected, absorbed, or transmitted through various materials.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and/or use a model to predict and/or describe phenomena.</td><td>PS4.A: Wave Properties
• A sound wave needs a medium through which it is transmitted.

PS4.B: Electromagnetic Radiation
• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light.
• The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass), where the light path bends.
• A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
• However, because light can travel through space, it cannot be a matter wave, like sound or water waves.</td><td>Structure and Function
• Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Emphasis is on both light and mechanical waves.
• Examples of models could include drawings, simulations, and written descriptions. This includes amplitudes, frequencies, and wave lengths.

Content Limits
• Assessment is limited to qualitative applications pertaining to light and mechanical waves, not quantitative.
• Assessment does not include:
    • Particle movement and compression waves
    • Constructive or destructive interference</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Refracted, medium, transparent, frequency, brightness, color, bending, amplitude, sound wave, light wave, path, propagation, filter, barrier, lens, mirror, mechanical waves, electromagnetic, visible light, ray, prism, wavelength.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Longitudinal wave, transverse wave, compression wave, seismic waves, radio wave, microwave, infrared, ultraviolet, x-rays, gamma rays, angle of incidence, concave, convex, diffraction, constructive interference, destructive interference</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-PS4-2:
• One part of a straw appears to be broken from the rest of the straw when viewed through the side of a glass of water.
• Music placed near a lake can be heard clearly while sitting on the shore. However, while swimming under the water, the sound cannot be heard as clearly.</td></tr>
</table>

	• Objects are more visible during a moonlit night when there is snow on the ground vs. when there is no snow on the ground. • Loud music moves the leaves of a plant.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select from a collection of potential model components including distractors, the components needed to model the phenomenon. Components might include type of wave, properties of the wave, the materials with which the waves interact, the position of the source of the wave, etc.	
2. Assemble, from a collection of potential model components, an illustration or flow chart that is capable of representing the movement, transmission, reflection, refraction, and absorption of waves. This does not include labeling an existing diagram.	
3. Manipulate the components of a model to demonstrate the changes that cause the observed phenomenon.	
4. Manipulate the components of a model to predict the behavior of waves in an alternate scenario.	
5. Given models or diagrams of how a wave interacts with different materials, identify the wave properties and how they change in each scenario OR identify the properties of the different materials that cause the wave to behave differently.	
6. Identify missing components, relationships, or other limitations of the model.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-PS4-3
Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Integrate qualitative scientific and technical information in written text with information contained in media and visual displays to clarify claims and findings.</td><td>PS4.C: Information Technologies and Instrumentation
• Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information</td><td>Structure and Function
• Structures can be designed to serve particular functions.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on a basic understanding that waves can be used for communication purposes.
• Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.
• Examples could also include using vinyl record vs. digital song files, film cameras vs. digital cameras, or alcohol thermometers vs. digital thermometers.

Content Limits
• Assessment does not include binary counting.
• Assessment does not include the specific mechanism of any given device.
• <u>Students do not need to know</u>:
o Specifics about binary or any other coding process.
o How certain mechanisms work other than the fact that they are either analog or digital.
o Students are not responsible for knowing the different parts of mechanisms: hard drives, USB cables, flash drives, and servers.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Computer, machine, communicate, electricity, device, coded, decode, conversion/convert, digitize, encode, radio wave</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Binary, emit, photoelectric, pixel, electromagnetic radiation, radiation, wave packet, wave source, ohm, photon, microwave, ultraviolet, volt, ampere.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for Standard MS-PS4-3:
• A digital scale gives better precision on weight measurements than analog.
• Digital films are higher quality than analog films (from a film reel).
• Digital measurements provide precise values compared to analog measurements
• Digital data can be stored in a server and easily retrieved if the hardware breaks, while analog data are lost if the hardware is broken.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Identify evidence that is sufficient to support the claim that digital signals are a more reliable way to store and transmit information than analog signals.
2. Citing evidence, identify specific features of digital signals that make them more reliable than analog signals OR identify specific examples of how digitization of a certain technology has advanced science.
3. Gather, read and synthesize information from multiple sources and assess the credibility, accuracy, and possible bias of each publication; describe how they are supported or not supported by evidence.
4. Evaluate data and/or conclusions in scientific and technical texts in light of competing information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS1-1
Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation.</td><td>LS1.A: Structure and Function
• All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).</td><td>Scale, Proportion, and Quantity
• Phenomena that can be observed at one scale may not be observable at another scale.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many varying cells.

Content Limits
• <u>Students do not need to know</u>:
○ The structures or functions of specific organelles or different proteins
○ Systems of specialized cells
○ The mechanisms by which cells are alive
○ Specifics of DNA and proteins or of cell growth and division
○ Endosymbiotic theory
○ Histological procedures.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Multicellular, unicellular, tissues, organ, system, organism hierarchy, bacteria, colonies, yeast, prokaryote, eukaryote, magnify, microscope, DNA, nucleus, cell wall, cell membrane, algae, chloroplast(s), chromosomes</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Differentiation, mitosis, meiosis, genetics, cellular respiration, energy transfer, RNA, protozoa, amoeba, histology, Protista, archaea, nucleoid, plasmid, diatoms, cyanobacteria.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS1-1:
• Plant leaves and roots have tiny box-like structures that can be seen under a microscope.
• Small creatures can be seen swimming in samples of pond water viewed through a microscope.
• Different parts of a frog’s body (muscles, skin, tongue, etc.) are observed under a microscope, and are seen to be composed of cells.
• One-celled organisms (bacteria, protists) perform the eight necessary functions of life, but nothing smaller has been seen to do this.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify from a list, including distractors, the materials/tools needed for an investigation to find the smallest unit of life (cell).</td></tr>
</table>

2. Identify the outcome data that should be collected in an investigation of the smallest unit of living things.
3. Evaluate the sufficiency and limitations of data collected to explain that the smallest unit of living things is the cell.
4. Make and/or record observations about whether the sample contains cells or not.*
5. Interpret and/or communicate data from the investigation to determine if a specimen is alive or not.
6. Construct a statement to describe the overall trend suggested by the observed data.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS1-2
Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model to describe phenomena.</td><td>LS1.A: Structure and Function
• Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.</td><td>Structure and Function
• Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts; therefore, complex natural structures/systems can be analyzed to determine how they function.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasize the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.

Content Limits
• Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane.
• Assessment of the function of the other organelles is limited to their relationship to the whole cell.
• Assessment does not include the biochemical function of cells or cell parts.
• <u>Students do not need to know</u>: protein synthesis, cell division (mitosis), reproduction (meiosis).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Eukaryote, prokaryote, nucleus, chloroplast, mitochondrion, cell membrane, cell wall, diffusion, osmosis, photosynthesis, cellular respiration, sugar, DNA, RNA, energy, bacteria, cytoplasm, organelle.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Golgi, ribosome, endoplasmic reticulum, enzyme, replication, mitosis, meiosis, glucose, chromosome, protein channels, lysosome, vacuole, peroxisome, thylakoid, stroma, granum, nuclear envelope, nucleolus, flagellum, cytoskeleton, microvilli, chromatin, plasmodesmata, microfilaments, microtubules, fimbriae, nucleoid, capsule, flagella, nucleoid, plasma membrane, cytosol, phagocytosis, endocytosis, cristae.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS1-2:
• Skin cells act as a barrier between your insides and the outside.
• Under a microscope, a muscle cell looks different than a skin cell.
• Under a microscope, a root cell looks different than a leaf cell.
• An E. coli bacterium is approximately the same size as the mitochondria of a mammalian lung cell.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete, from a collection of potential model components, an illustration that is capable of representing a eukaryotic (plant and/or animal) or prokaryotic cell in terms of the function of the cell.</td></tr>
<tr><td colspan="4">2. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might mirror the cell wall, cell membrane, nucleus, chloroplast, and/or mitochondrion. This <u>does not</u> include labeling an existing diagram.</td></tr>
</table>

3. Manipulate the components of a model to demonstrate the changes, properties, and/or events that act to result in the phenomenon.*
4. Given models or diagrams of cells, identify the functions of each part of the cell.
5. Identify missing components, relationships, or other limitations of the model.
6. Describe, select, or identify the relationships among components of a model that together function as a cell.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS1-3
Use argument supported by evidence for how the body is a system of interacting sub-systems composed of groups of cells.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.</td><td>LS1.A: Structure and Function
• In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.</td><td>Systems and System Models
• Systems may interact with other systems; they may have sub-systems and be part of larger complex systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.

Content Limits
• Assessment does not include the mechanism of one body system independent of others.
• Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular and nervous systems.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Organization, organ, organ system, response, internal cue, life-sustaining functions, muscular system, anatomy, aorta, artery, automatic, bone, bone marrow, brain, brain stem, cerebellum, cerebrum, circulatory system, connective tissue, cornea, digestive system, gland, lens, muscle, muscle cell, reflex, sensory, skeletal system, tissue, respiratory, vertebrate, invertebrate, reproduction, breed, heart, lungs, heart rate</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Destabilize, excitatory molecule, feedback mechanism, hierarchical, homeostasis, inhibitory molecule, immune system, living system, neural, organic compound synthesis, protein structure, protein synthesis, regulate, stabilize, stomate, system level, transform/transport matter/and or energy, excretion, limiting factor, voluntary muscle, pancreas, sensory fiber, sensory nerve, root development</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS1-3:
• After falling and scraping your knee, a scab forms over the wound.
• An elephant’s heart rate is slower than a mouse’s heart rate even though it is much bigger.
• A person swallows their food while doing a handstand, but a bird cannot swallow food while hanging upside down.
• When a person hasn’t eaten in a few hours and is hungry, their stomach makes an audible “growling” sound.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Based on the provided data, identify, describe or illustrate a claim regarding the relationship between cells, tissues, organs and bodily function(s).</td></tr>
<tr><td colspan="4">2. Identify, summarize, or organize given data or other information to support or refute a claim regarding the relationship between cells, tissues, organs and bodily function(s).*</td></tr>
</table>

3. Sort inferences about the relationship between body systems into those that are supported by the data, contradicted by the data, or neither, or some similar classification.*
4. Select supporting evidence from competing sources based on the reliability of statistical relationships, how representative the sample is, or study design to show how the body is a system of interacting subsystems.
5. Construct an argument using scientific reasoning drawing on credible evidence to explain the relationships of interacting subsystems in a body such as tissues and organs. (Hand scored CR) *
6. Identify additional evidence that would help clarify, support, or contradict a hypothesized relationship or causal argument regarding the interactions of subsystems in the body.
7. Identify or describe alternate explanations and the data needed to distinguish among them in order to explain how body system functions.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS1-4
Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.</td><td>LS1.B: Growth and Development of Organisms
• Animals engage in characteristic behaviors that increase the odds of reproduction.
• Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.</td><td>Cause and Effect
• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements:
• Examples of behaviors that affect the probability of animal reproduction could include: nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding.
• Examples of animal behaviors that affect the probability of plant reproduction could include: transferring pollen or seeds, and creating conditions for seed germination and growth.
• Examples of plant structures could include: bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.

Content Limits:
• Data analysis should be limited to calculations and interpretation of measures of central tendency.
• Students are only expected to understand probability as expected relative frequency.
• Students can be asked to evaluate whether sample data are representative and the limits to which findings can be generalized.
• Data sets can include not only common trends but also outliers and anomalous data points.
• <u>Students do not need to know</u>: Mechanisms or patterns of inheritance, meiosis, specific reproductive structures not detailed within this document (e.g., nuptial pads, dulap), detailed life cycles.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Nest, herd, mate, breed, probability, behavior, pollen, flower, petal, seed, fruit, nectar, germination, vocalization, plumage, pollination</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Symbiosis, mutualism, commensalism, parasitism, gametophyte, sporophyte, carpal, sepal, pistil, anther, stamen, ovule, “alternation of generations,” sporangia, monoecious, dioecious.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS1-4:</td></tr>
</table>

	• Spring peepers (*Pseudacris crucifer*) in South Georgia, North Georgia, and Eastern Kentucky begin vocalizing (breeding) at different times of the year. • Female poison arrow frogs lay their eggs in leaf litter. When they hatch, male poison arrow frogs herd the tadpoles onto their backs and transport them to bromeliads, where they develop into adulthood. • The proportion of trees that are pollinated by insects decreases with latitude (phenomenon would be data tables that illustrate this relationship). • The Aspen tend to be one of the first plants to emerge after a forest fire.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data, identify, describe or illustrate a claim regarding the relationship between a characteristic animal behavior and/or specialized plant structure and the probability of successful reproduction in the species.
2. Identify, summarize, or organize given data or other information to support or refute a claim regarding the relationship between a characteristic animal behavior and/or specialized plant structure and the probability of successful reproduction in the species.
3. Sort inferences about the relationship of behaviors or structures to breeding success into those that are supported by the data, contradicted by the data, or neither, or some similar classification.
4. Select supporting evidence from competing sources based on the reliability of statistical relationships, how representative the sample is, or study design.
5. Construct an argument using scientific reasoning drawing on credible evidence to explain the relationships of animal behaviors or plant structures to reproductive success. (Hand scored CR)
6. Identify additional evidence that would help clarify, support, or contradict a hypothesized relationship or causal argument.
7. Identify or describe alternate explanations and the data needed to distinguish among them.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS LS1-5
Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS1.B: Growth and Development of Organisms
• Genetic factors as well as local conditions affect the growth of the adult plant.</td><td>Cause and Effect
• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of local environmental conditions could include availability of food, light, space, and water.
• Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms.
• Examples of evidence could include a drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.

Content Limits
• Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.
• Assessment does not include Punnett squares.
• <u>Students do not need to know</u>: epigenetics or variations of gene expression.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Gene, genetics, genome, genotype, phenotype, environment, growth, development, DNA.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Epigenetics, RNA, gene expression, photoperiod.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Phenomena for this performance expectation should include two groups of a particular organism with one environmental change.

Some example phenomena for MS-LS1-5:
• An orchard contains both full-sized and dwarf apple trees. Individuals of both types of tree grow shorter and produce fewer apples when planted on a dry hillside, and grow taller and produce more apples when planted on the shore of a pond. (i.e., the full apple trees on the hillside are the same size with similar apple production as the dwarf apple trees by the pond).
• Only about 90% of identical twins each have the same height.</td></tr>
</table>

	• A group of poinsettias and daisies are grown in the same greenhouse. The poinsettias bloom when exposed to ten consecutive hours of light, but the daisies bloom when exposed to 14 consecutive hours of light. • Burrs are dispersed to different environments by traveling on the fur of mammals. Some seeds from a burr plant drop off into a sunny field, while others drop off into a shady patch of woods. The burr plants that grew in the sun are taller and produced more burrs than those that grew in the shade.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select genetic and/or environmental influences on phenotypic differences between organisms. This may entail sorting relevant from irrelevant information.
2. Explain the process by which genetic factors and/or local conditions cause the observed phenomenon, supporting the explanation with valid and reliable evidence (hand scored).
3. Identify evidence that supports the inference that genetic and environmental factors influence growth and development of organisms. Environmental factors may include food, light, space, and water.
4. Describe, identify, and/or select information from one or more sources to support an explanation for phenotypic differences in organisms related to genetic and environmental factors.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS1-6
Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

PS3.D: Energy in Chemical Processes and Everyday Life
• The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen (secondary).</td><td>Energy and Matter
• Within a natural system, the transfer of energy drives the motion and/or cycling of matter.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on tracing movement of matter and flow of energy.
• Students are able to identify relationships between dependent and independent variables.

Content Limits
• Assessment does not include the biochemical mechanisms of photosynthesis.
• Assessment does not include the carbon cycle or nitrogen fixation.
• <u>Students do not need to know:</u> how to balance chemical equations.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Glucose, algae, consumer, product, transformation, conservation, convert, decomposer, aquatic, organic, phytoplankton, producer, reaction, carbon, carbon dioxide, chemical process, chemical reaction, molecule, nutrient, moisture, structure, organic matter, stimulus, tissue, hydrogen</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Biomass, biological molecule, compound, flow of matter, hydrocarbon, net transfer, photosynthesizing organism, carbon cycle, efficient, excitatory molecule, molecular synthesis, organic compound synthesis, stomata</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS1-6:
• A plant is kept in a clear, closed container that allows sunlight to pass through. After one week, the plant is dead. A mouse kept alone in the same container also dies. However, a plant and mouse kept together in the same container after one week are alive.
• The plant Elodea releases bubbles at an increased rate when an aquatic animal is added to the same aquarium.</td></tr>
</table>

	• A plant grows in a pot of soil for one month. Only water is added to the pot. After one month, the plant has gained mass, while the mass of the soil has barely changed. • A plant leaf kept in the light contains large amounts of starch, while a leaf kept in the dark does not.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products.	
2. Express or complete a description of the flow of energy and/or matter among organisms. This may include indicating directions of causality in an incomplete model (including food webs), such as a flow chart or diagram.	
3. Identify evidence that photosynthesis cycles matter and energy through an ecosystem.	
4. Select, identify, or describe the predicted effect of a change of conditions on the flow of energy and matter among organisms.	
5. Describe, identify, and/or select information needed to support an explanation.	

Performance Expectation	**MS-LS1-7** Develop a model to describe how food is rearranged through chemical reactions to form new molecules that support growth and/or release energy as this matter moves through an organism.		
Dimensions	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, support growth, or release energy. **PS3.D: Energy in Chemical Processes and Everyday Life** • Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. *(secondary)*	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on the describing that describing that molecules are broken apart and put back together and that in this process energy is released. **Content Limits** • Assessment does not include details of the chemical reactions for photosynthesis or respiration. • Students do not need to know: enzymes, ATP synthase, metabolism, biochemical pathways, redox reactions, molecular transport, specific enzymes involved, catalysts		
Science Vocabulary Students are Expected to Know	Oxygen, carbon dioxide, water, sugar, glucose (including chemical formula), ATP, chemical bonds, photosynthesis, proteins, enzymes, organelles, nucleus, DNA, mitochondria, cytosol, cytoplasm, nitrogen		
Science Vocabulary Students are Not Expected to Know	Biochemical, fatty acids, oxidizing agent, electron acceptor, biosynthesis, locomotion, phosphorylation, electron transport chain, chemiosmosis, pyruvate, pentose, adenine, phosphate, amino acid, fermentation, aerobic respiration, redox reactions, oxidation, reduction, reducing agent, oxidizing agent, NAD+, transport chain, glycolysis, citric acid cycle, oxidative phosphorylation, substrate-level phosphorylation, acetyl CoA, cytochromes, chemiosmosis, ATP synthase, lactic acid		
Phenomena			
Context/ Phenomena	Some example phenomena for MS-LS1-7: • A young plant is grown in a bowl of sugar water. As it grows, the amount of sugar in the water decreases. • A person feels tired and weak before they eat lunch. After they eat some fruit, they feel more energetic and awake. • An athlete completing difficult training feels that their muscles recover and repair faster when they eat more high-protein foods in a day compared to when they eat less protein in a day. • Amoeba are provided food in a petri dish. When fed, the amoeba become more active and begin to grow and divide		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			

1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include gases, sugars, and organelles.
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing the transformation of food + oxygen into energy and/or new compounds. This does not include labeling an existing diagram.
3. Manipulate the components of the model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
4. Make predictions about the effects of changes in the type or amount of a certain component in the model. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Given models or diagrams of the state of model components, identify the properties of the system that give rise to the phenomenon.
6. Identify missing components, relationships, or other limitations of the model.
7. Describe, select, or identify the relationships among components of a model that describe or explain how food can be turned into energy for new growth and other activities.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS1-8
Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.</td><td>LS1.D: Information Processing
• Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• Assessment does not include mechanisms for the transmission of information from sensory receptors to the brain.
• <u>Students do not need to know</u>: Sensory transduction, ion channels, action potentials, sensory and motor cortices in the brain.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Memory, perception, transmit, accuracy, immediate, nerve, receptor, sense receptor, sensory, behavioral response to stimuli, electromagnetic, stimulus, short-term memory, long-term memory, salt, sour, sweet, bitter, brain, nervous system, taste, smell, touch, hear, sight</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Neuron, neurotransmitter, endocrine signaling, synapse, axon, olfactory, rods, cones, trichromatic vision, retina, hair cells, cochlea, fight-or-flight response, sensitization, depolarization, taste papillae, umami,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS1-8:
• A woman closes her eyes and touches the tip of her nose with her index finger.
• A student is studying in a library. The fire alarm goes off and he involuntarily jumps out of his chair.
• A woman walking past a bakery smells cinnamon and is instantly reminded of her grandmother’s house.
• A driver sees a stoplight change from green to red and quickly moves his foot from the accelerator pedal to the break.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols and mathematical representations to describe how external stimuli are sensed by the brain.</td></tr>
<tr><td colspan="4">2. Assemble or complete an illustration or flow chart representing physiological or behavioral responses to external stimuli.</td></tr>
<tr><td colspan="4">3. Based on the information provided, identify or describe supporting evidence for an argument regarding the relationship between an external stimulus, sensory receptors and/or a particular behavior.</td></tr>
</table>

4. Make predictions about the effects on sensory receptors, immediate behavior, or memory storage as a result of changes to an external stimulus. Predictions can be quantitative or qualitative and can be made by completing illustrations, or selecting from lists with distractors.
5. Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.
6. Synthesize an explanation regarding sensory stimuli that incorporates scientific evidence from multiple sources.
7. Identify, summarize, or organize given data or other information to support or refute a claim relating the characteristics of an external stimulus to a sensory pathway.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS2-1
Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to provide evidence of phenomena.</td><td>LS2.A: Interdependent Relationships in Ecosystems
• Organisms, and populations of organisms, are dependent on their environmental interactions, both with other living things and with nonliving factors.
• In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
• Growth of organisms and population increases are limited by access to resources.</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on cause and effect relationships between resources and growth of individual organisms, and the numbers of organisms in ecosystems during periods of abundant and scarce resources.
• Examples could include water, food, and living space

Content Limits
• Assessment does not include mathematical and/or computational representations of factors related to carrying capacity of ecosystems of different sizes (including deriving mathematical equations to make comparisons).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Resource, competition, ecosystem, nutrient, food chain/web, producer, consumer</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Biotic component, abiotic component, exponential (AKA “logistic”) growth, ecological niche, resource partitioning, fundamental niche, realized niche, carrying capacity, interspecific competition, intraspecific competition, biomass, carrying capacity</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">The phenomena for this performance expectation are the given data. Samples of phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc.).

Some example phenomena for MS-LS2-1:
• On the north Atlantic coastline, two species of barnacles live at different depths
• Cheetahs and leopards in the savannah use the same watering holes.
• After a drought period, the population of grasshoppers is halved.
• A garden is cleared of aphids. After a few days, the ladybirds in the surrounding trees are gone.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
6. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations between resource availability and the growth of a population or populations of organisms.	
7. Generate or construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations between resource availability and the growth of a population or populations of organisms. This may include sorting out distractors.*	
8. Use relationships identified in resource/population data to predict the change in a population or populations or the change in resources that resulted in a change in populations.**	
9. Identify patterns or evidence in the data that supports inferences and explanations about how resource availability affects a population of organisms.*	
10. Construct or identify testable questions that can be asked to collect data about how resource availability may affect the growth of a population or populations of organisms.	
11. Identify, describe, or select from a collection characteristics to be manipulated or held constant while gathering information to answer a well-articulated question.*	
12. Select or describe inferences relevant to the question posed and supported by the data, especially inferences about causes and effects.	
13. Select, identify, or describe predicted outcomes when specific changes in resource availability occur, using inferences about cause and effect relationships involving those resources.**	

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD3 and TD8 must be used together.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS2-2
Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.</td><td>LS2.A: Interdependent Relationships in Ecosystems
• Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.</td><td>Patterns
• Patterns can be used to identify cause and effect relationships.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between living organisms and nonliving components of ecosystems.
• Examples of types of interactions could include competitive, predatory, and mutually beneficial.

Content Limits
• Analysis may include recognizing patterns in data, specifying and explaining relationships, making logical predictions from data, retrieving information from a table, graph or figure and using it to explain relationships, generating hypotheses based on observations or data, and generalizing a pattern.
• Analysis should not include relating mathematical or scientific concepts to other content areas.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">relative, disperse, ecological role, host, infection, mutualism, mutually beneficial, parasite, evolve, genetic, interdependent</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">abiotic</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation, the phenomena are sets of data. Those are the observed facts that the students will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed. Patterns should be observed across at least two different environments/habitats.

Patterns that describe the data sets for MS-LS2-2:
• The tongue of the alligator snapping turtle looks like a small worm. The turtle uses this tongue to lure prey close to its mouth. (Predation)—also angler fish.</td></tr>
</table>

	• Higher density of squirrels in oak environment than in maple environment. • Hippopotamuses spend time in both aquatic and savannah ecosystems. When found in aquatic environments, they're often surrounded by carp. When found in a savannah environment, they're often surrounded by oxpeckers. • In Ecuador's Andean Cloud Forest, a hummingbird feeds on the nectar of an orchid flower (*Epidendrum secundum*). In the Madagascar, a similar orchid flower (*Angraecum sesquipedale*) is seen, but no hummingbirds are found.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships or interactions to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain common or distinct across organisms or environments. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause and effect chains.*
3. Identify evidence supporting the inference of causation of patterns of interactions among organisms across multiple ecosystems expressed in a causal chain.*
4. Use an explanation to predict interactions among different organisms or in different environments.
5. Describe/Identify/Select information needed to support an explanation of patterns of interactions among organisms across multiple ecosystems.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS2-3
Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model to describe phenomena.</td><td>LS2.B: Cycle of Matter and Energy Transfer in Ecosystems
• Food webs are models that demonstrate how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.</td><td>Energy and Matter
• The transfer of energy can be tracked as energy flows through a natural system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasize food webs and the role of producers, consumers, and decomposers in various ecosystems.
• Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.

Content Limits
• Students do not need to identify biomes or to know information about specific biomes.
• Assessment does not include
o The use of chemical reactions to describe the processes.
o Identification of trophic levels, understanding of the relative energies of the trophic levels, nor the knowledge of the 10% energy transfer between trophic levels.
o The process of bioaccumulation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Producer, consumer, decomposer, herbivore, omnivore, carnivore, algae, fungi, microbe, microorganism, organic matter, organic waste, photosynthesis, atom, molecule, sugar, carbon, carbon dioxide, nitrogen, oxygen, predator, prey, aquatic, interdependent, chemical reaction, reactant, product</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biotic, abiotic, trophic level, energy pyramid, nitrogen fixation, exothermic/endothermic, detritivores, biomass, bioaccumulation/biomagnification, autotroph/heterotroph, biosphere, hydrosphere, geosphere, aerobic, anaerobic, phosphorous, phytoplankton.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS2-3:
• In the Alaskan tundra, more grass and wildflowers grow on top of underground fox dens than elsewhere.
• In July, a colony of lava crickets is found to inhabit lava flows from a May eruption, but the first plant does not appear in the area until November.
• Fox-inhabited islands in the Aleutian Islands have less vegetation than islands not inhabited by foxes.
• Giant clams and tube worms are found in the darkest parts of the oceans in the hot water near hydrothermal vents.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Identify, assemble, or complete from a collection of potential model components, including distractors, components of a food-web model that describe transfers of matter and/or energy among producers, consumers, decomposers, or some subsets of those, potentially including transfers between living and nonliving organisms.	
2. Describe, select, or identify the relationships among components of a food-web model that describes how parts of the food web (producers, consumers, and decomposers) interact to continually cycle matter and to transfer energy among living and nonliving parts of an ecosystem.	
3. Manipulate the components of a food-web model to demonstrate how the interactions among producers, consumers, and/or decomposers result in changes to the cycling of matter and/or transfer of energy among living and nonliving parts of an ecosystem.	
4. Select, describe, or illustrate predictions about the effects of changes in the organisms or nonliving components of the environment on the cycling of matter, transfer of energy, and/or other organisms in the environment. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.	
5. Select or identify missing components or relationships of a food web model that describes the transfers of matter and/or energy among living and nonliving parts of an ecosystem.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS2-4
Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.</td><td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• Ecosystems are dynamic in nature: their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.</td><td>Stability and Change
• Small changes in one part of a system might cause large changes in another part.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.

Content Limits
• Assessment does not include the use of chemical reactions to describe the processes.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Predator, prey, mutually beneficial interactions, competition, consumers, producers, decomposers, biodiversity.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Carrying capacities, anthropogenic changes, biomass</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Example Phenomena for MS-LS2-4:
• After a beaver builds a dam, the amount and diversity of fish life in a stream increases.
• After wolves were reintroduced to Yellowstone, there were more willows.
• The number of willows has increased in Yellowstone. (Give two competing hypotheses: wolf introduction; beaver population increase).
• As the Aral Sea declined in size since the 1960s, salinity has increased and the Aral trout is no longer present in the lake.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or information supporting/refuting one or more competing hypotheses.</td></tr>
<tr><td colspan="4">2. Predict outcomes when changes to an ecosystem occur, given the inferred cause and effect relationships.*</td></tr>
<tr><td colspan="4">3. Identify, select, and/or describe information or evidence needed to support one or more potentially competing explanations.</td></tr>
</table>

4. Identify patterns of information/evidence in the data that support correlative/causative inferences about the relationships among the pertinent parts of an ecosystem.*
5. Organize and/or arrange (e.g., using illustrations and/or labels) or summarize population data to highlight trends, patterns, or correlations.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS2-5
Evaluate competing design solutions for maintaining biodiversity and ecosystem services.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.</td><td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health.

LS4.D: Biodiversity and Humans
• Changes in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, fresh air and water (secondary).

ETS1.B: Developing Possible Solutions
• There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (secondary).</td><td>Stability and Change
• Small changes in one part of a system may cause a large change in another part.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion.
• Examples of design solution constraints could include scientific, economic, and social considerations.

Content Limits
• <u>Students do not need to know:</u> specific policies or specific details of organisms.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Habitats, niche, native species, non-native or invasive species</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Specific species names, specific resource or habitat requirements for any species.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering performance expectations are built around meaningful design problems rather than phenomena. In this case, the design problems involve preserving ecosystems and protecting biodiversity. For this performance expectation, the design problem and competing solutions replace phenomena.

Some example design problems for MS-LS2-5:
• Giant African Land Snails were brought to Florida by a boy who smuggled three snails into Florida. His grandmother released these into a garden and the snail population exploded. The snails eat over 500 plant species, tree bark, paint, and even stucco. Florida has implemented four solutions:</td></tr>
</table>

	o Trained dogs that sniff out snails for capture. o Chemicals applied to plants that the snails feed upon. o Predatory species to eat the snails. • The brown tree snake was accidentally brought to the island of Guam by ships during World War II, fed on native birds until the Guam rail, a native bird, nearly went extinct in 1984. Guam has implemented two solutions: o Feed rats acetaminophen and drop them into wooded areas. o Bring in predatory species to eat the snakes. • Cheatgrass, a type of weed that was brought to the United States in the late 1800s, has spread all over Utah from the desert valleys to the mountains, growing faster than most native plants. Utah has implemented two solutions: o Use genetically modified seeds for certain native seeds that are heartier than the Cheatgrass to push out the Cheatgrass seeds. o Controlled application of herbicides. • Asian carp is an aggressive fish species introduced in 1960 to control weed populations in waterways in southern fish farm ponds. The population was sterilized but a few fertile fish escaped into the Mississippi River and migrated north towards the Great Lakes. Asian carp are an invasive species that compete with native fish in the Great Lakes and threaten the ecosystem balance. Regions around the Great Lakes are implementing strategies: o Launch a campaign to encourage and incentivize fishing of Asian carp for human consumption o Use a system of electric barriers to prevent Asian carp from entering Lake Michigan from the Mississippi River. o Use nets to block paths to popular spawning sites during Asian carp reproduction season. o Introduce a botanic pesticide used for fish eradications in water areas known to have large Asian carp populations.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify or assemble from a collection, including distractors, the relevant aspects of the problem that, given design solutions if implemented, will resolve/improve maintaining biodiversity and ecosystem services.
2. Using given information for maintaining biodiversity and ecosystem services, select or identify constraints that the device or solution must meet.
3. Using the given information for maintaining biodiversity and ecosystem services, select or identify the criteria against which the device or solution should be judged.
4. Compare, rank, or otherwise evaluate the different design solutions for maintaining biodiversity and ecosystem services against the identified criteria.
5. Select or propose a recommended course of action supported by the design solution's ability to meet identified criteria.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS3-1
Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of an organism.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using a Model
• Develop and use a model to describe phenomena.</td><td>LS3.A: Inheritance of Traits
• Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

LS3.B: Variation of Traits
• In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Through rare, mutations my result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.</td><td>Structure and Function
• Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among their parts; therefore, complex natural structures/systems can be analyzed to determine how they function.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the conceptual understanding that changes in genetic material may result in making different proteins.

Content Limits
• Assessment does not include specific changes of genes at the molecular level, mechanisms for protein synthesis, and specific types of mutations.
• Do not use examples of mutations in humans.
• Analysis does not include species-level sources of genetic variation, including the founder effect, bottleneck, genetic drift or Hardy-Weinberg equilibrium.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Genome, genotype, phenotype, DNA, pedigree, parent generation, trait, positive, negative, neutral, pollination, Punnett square, dominant trait, recessive trait, allele</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">RNA, transcription, translation, mitosis, meiosis, interphase, prophase, metaphase, anaphase, telophase, cytokinesis, zygote, fertilization, codominance, incomplete dominance, sequencing, F1, F2, haploid, diploid, epigenetics, plasmid.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS3-1:
• Use of antibiotics in farming has leeched antibiotics into the water system. However, resistant bacteria persist in groundwater and are difficult to kill.</td></tr>
</table>

	• Wild almond trees produce the poisonous chemical amygdalin. Occasional individual almond trees have a mutation that cause them not to produce amygdalin. These individual plants are cultivated on almond farms. • A farmer observed one corn plant producing corn cobs with larger kernels. The farmer planted seeds from that plant and the offspring corn plants also had larger kernels. • Thale cress plants sprout in the spring and flower about a month later.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Select or identify from a collection of potential model components, including distractors, the components needed to model a phenomenon. Components might match a phenotypic change resulting from a mutation to various environments, to determine whether a mutation is beneficial, harmful, or neutral to the individual.
2. Assemble or complete, from a collection of potential model components, an illustration that is capable of representing the effects of a mutation in an individual in a specific environment. This does not include labeling an existing diagram.
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in a phenomenon.
4. Make predictions about the effects of changes in an organism’s ability to survive and reproduce based on the mutation and/or environment. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Given models or diagrams of phenotypic changes due to mutation, identify and describe why the mutation may positively, negatively, or neutrally affect the individual in different environments.
6. Identify or select the relationships among components of a model that describe the rationale behind the beneficial, harmful, or neutral nature of a mutation in specific environments.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS3-2
Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model to describe phenomena.</td><td>LS1.B: Growth and Development of Organisms
• Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring (secondary).

LS3.A: Inheritance of Traits
• Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.

LS3.B: Variation of Traits
• In sexually reproducing organisms, each parent contributes (at random) half of the genes acquired by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using models such as Punnett Squares, diagrams and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.

Content Limits
• Assessment does not include phases of mitosis or meiosis.
• <u>Students do not need to know</u>: process of recombination</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Development, germination, plant structure, plumage, reproductive system, fertilizer, allele, dominant trait, recessive trait, hereditary information, Punnett square, transmission, protein, DNA</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">DNA replication, sex-linked trait, recombination, gene expression, segment, sex cell, sex chromosome, cell division, mutation, meiosis, amino acid, amino acid sequence, haploid, diploid</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS3-2:
• Jellyfish will produce both clones and genetically diverse offspring during different stages of their life cycle.
• Strawberry plants grow another stem from a core stem that extends horizontally on the ground. This new stem will become a separate strawberry plant.
• A flatworm is cut in half. Rather than dying, both halves regenerate their lost portions to form two new, distinct, and fully functioning worms.</td></tr>
</table>

	• A plant (*Bryophyllum diagremontianum*) native to Madagascar has what appears to be miniature clusters of leaves lining the edges of a much larger leaf.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include alleles, genotypes, and phenotypes.
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing different types of reproduction. This *does not* include labeling an existing diagram.
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in a phenomenon.
4. Make predictions about the effects of genetic variation from reproduction. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Given models or diagrams of types of reproduction, identify the types of reproduction and how they change in each scenario OR identify the properties of the different types of reproduction that cause genetic variation.
6. Identify missing components, relationships, or other limitations of the model.
7. Identify, calculate, or select the relationships among the components of a model that describe the types of reproduction, the environmental conditions under which reproduction occurs, or explain the genetic variation that results from reproduction.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS4-1
Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth, under the assumption that natural laws operate today as in the past.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to determine similarities and differences in findings.</td><td>LS4.A: Evidence of Common Ancestry and Diversity
• The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.</td><td>Patterns
• Graphs, charts, and images can be used to identify patterns in data.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.

Content Limits
• Does not include: genetic analysis, comparisons of fossils to extant organisms, embryological evidence, genetic variation, inheritance, selective pressures.
• <u>Students do not need to know</u>: the names of individual species/genera or intervals of geological time, taxonomy, processes of fossil formation.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Sedimentary rock, volcanic rock, radioactive dating, mineral, extinct, unicellular, multicellular, organelles, nucleus, ancestor, ancestry, species, evolve, anatomical.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Cladogram, phylogenetics, phylogenetic systematics, phylum/phyla, class, order, family, genus/genera, homologous, analogous, divergent, convergent, prokaryote, eukaryote.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation the phenomena are sets of data. These are the observed facts that the kids will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed.

Stimuli might commonly include one or more geological column, data on what fossils are found in that (those) column(s), and the characteristics of those fossils. When more than one column is to be used in the analysis, sufficient data are given to anchor the ages of one or more key strata. Students would set out to identify and articulate patterns in the data.

Patterns that describe the data sets for MS-LS4-1:
• The first feather-like structures, associated with dinosaurs, appear in the fossil record close to 200 million years ago. Over the next 50 million years, a great variety of dinosaurs and true birds appeared, showing a great variety of feathers.</td></tr>
</table>

	• In North America, in the late C, a diverse assemblage of fossils is found. In the early Tertiary, there are far fewer types of fossils. • Prior to 542 million years ago, the fossil record shows relatively simple organisms without much variation. Layers in the fossil record between 542 million years ago to 476 million years ago shows the Cambrian Explosion—a time of significant evolution of animals, beginning with trilobites and ending with vertebrate fish. The Cambrian Explosion closed with a major extinction. • 525-year-old rock layers contain the earliest vertebrate fossils, which are of fish. These fossil fish had a cartilage skull with no jaw, and lacked a vertebral column. Fossils in 450-million-year-old rocks include vertebrate fish with a cartilage jaw and vertebral column. 400-year-old rocks include fish with skulls that include jaws and vertebrates made of bone.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize and/or arrange (e.g., using illustrations and/or labels) data that document patterns of change in the fossil record related to changes in anatomical structures or organism appearance/disappearance.
2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns of change in the fossil record related to changes in anatomical structures or organism appearance/disappearance. This may include sorting out distractors.
3. Determine or describe evidence that supports data on the timing of a mass extinction event, emergence/extinction of a new species/trait, and/or patterns of changes in biodiversity and organism complexity over time.
4. Identify/describe/illustrate/assemble sequences over time describing changes in characteristics of organisms, the diversity of the characteristics, the diversity of organisms, or the relative frequencies of the characteristics. This may include selecting a pattern from a list.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS4-2
Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.</td><td>LS4.A: Evidence of Common Ancestry and Diversity
• Anatomical similarities and differences among organisms living today, and between contemporary organisms and those in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.</td><td>Patterns
• Patterns can be used to identify cause and effect relationships.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on explanation of the relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.
• Emphasis is on using anatomical similarities and differences to infer relationships among different modern organisms.
• Emphasis is on understanding that the changes over time in the anatomical features seen in fossil records can be used to infer relationships between extinct organisms to living organisms.
• Emphasis is on understanding that organisms that share a pattern of anatomical features are likely to be more closely related than are organisms that do not share a pattern of anatomical features.

Content Limits
• <u>Students do not need to know:</u> name of specific fossil species; knowledge of specific fossils or anatomical features; genetic variation, process of fossil formation, knowledge of geologic time periods; knowledge of rock layer; relationship between fossils and age of rock layers; molecular homology (similarities in DNA, RNA, and protein sequence).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Homologous, analogous, diversity, extinction, radioactive dating, mineral, extinct, unicellular, multicellular, organelles, ancestry, species, evolve</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Cladogram, phylogenetic tree, dichotomous tree, phylum/phyla, class, order, family, genus/genera, divergent, convergent, prokaryote, eukaryote, types of rock (sedimentary, volcanic rock, igneous, metamorphic), embryology.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS4-2:
• Bats and frogs have forelimbs that look very different, but have similar bones and overall structure.
• Comparing the skull bones of the modern-day whale to the fossilized skulls of Dorudon and Pakicetus, shows a pattern in the position of the nostril as these organisms changed over millions of years.</td></tr>
</table>

	• Wings are structures that allow most birds to fly, except penguins, which have wings but cannot fly. • Modern-day whales live in the ocean but have small hind-legs.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.	
2. Express or complete a causal chain explaining how homologous structures show common ancestry and analogous structures show common function. This may include indicating directions of causality in an incomplete model, such as a flow chart or diagram, or completing cause and effect chains.*	
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.	
4. Describe, identify, and/or select information needed to support an explanation.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS4-3
Analyze displays of pictorial data to compare patterns of similarities in embryological development across multiple species to identify relationships not evident in the fully formed anatomy.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze displays of data to identify linear and nonlinear relationships.</td><td>LS4.A: Evidence of Common Ancestry and Diversity
• Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy.</td><td>Patterns
• Graphs, charts, and images can be used to identify patterns in data.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic of diagrams or pictures.

Content Limits
• Assessment of comparisons is limited to observable (with the naked eye) appearances of anatomical structures in embryological development.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Species, mammal, reproduce, mitosis, meiosis, body structure, limb, fetus, organ, tissues, cells.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Placenta, homologous structures, external/internal fertilization, zygote, differentiation, gamete, blastula, mesoderm, endoderm, ectoderm, notochord.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation, the data will consist of pictures, diagrams, etc. Students will be challenged to find patterns and similarities.

Some example phenomena for MS-LS4-3:
• Early mammal embryos and early fish embryos both contain gill slits. In fish embryos, these gill slits develop into gills. In human embryos, the gill slits disappear before birth.
• The embryos of chickens, humans, and koalas have tails, and muscles to move the tails. However, as the embryos develop, the tails disappear.
• The limb buds of early bird embryos are very similar to the limb buds of early human embryos. The limb buds of the bird embryos become wings, while the limb buds of human embryos become arms.
• The early embryos of fish, birds, rabbits, and humans all have two-chambered hearts.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Summarize data to highlight trends, patterns, or correlations in the similarities or differences of the embryonic development of different species.</td></tr>
</table>

2. Use relationships identified in the patterns of embryology data to predict the relatedness of different species.
3. Construct a statement that can potentially explain the observed trends or relationships in embryology data.
4. Identify patterns or evidence in the data that support inferences about the development of different species.
5. Identify additional information needed to support or challenge inferences based on identified patterns.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS4-4
Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena.</td><td>LS4.B: Natural Selection
• Natural selection leads to the predominance of certain traits in a population, and the suppression of others.</td><td>Cause and Effect
• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using simple probability statements and proportional reasoning to construct explanations.
• Emphasize the use of proportional reasoning to support explanations of trends in changes to populations over time.
• Examples could include camouflage, variation of body shape, speed and agility, or drought tolerance.

Content Limits
• <u>Students do not need to know</u>: dominant/recessive traits, modes of inheritance (polygenic, sex-linked, etc.).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Diversity, trend, predation, abundance, evolve/evolution, allele, sexual reproduction, beneficial, probability, distribution, adaptation, adaptive characteristics, frequency, DNA, dominant traits, recessive traits,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Gene expression, polygenic traits, sex-linked traits, mutation, advantageous, cline, microevolution, gene pool, genetic drift, founder effect, bottleneck effect, gene flow, relative fitness.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS4-4:
• The orchid mantis attracts pollinators of the orchid as prey.
• In New Mexico, the rock pocket mice found in dark, rocky areas of the Valley of Fire all have dark fur.
• Male frigate birds with larger red pouches are more likely to find a mate.
• Some Staphylococus aureus bacteria are able to survive following treatment with the antibiotic methicillin.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe or select the relationships, interactions, or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Complete a causal chain explaining how genetic variation affects the probability of survival and reproduction. This may include indicating directions of causality in a flow chart, diagram, or cause and effect chain.</td></tr>
</table>

3. Identify evidence supporting the role of genetic variation in determining the probability of survival and reproduction of an organism.
4. Predict changes in the frequency of a trait, given a change in the environment.
5. Identify the information needed to support an explanation for how genetic variation affects the rate of survival and reproduction.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS4-5
Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating
• Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and method used, and describe how they are supported or not supported by evidence.</td><td>LS4.B: Natural Selection
• In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.</td><td>Cause and Effect
• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, and gene therapy) and on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.

Content Limits
• <u>Students do not need to know</u>: overlapping DNA sequences, Hardy-Weinberg calculations, biodiversity, mechanisms of gene transfer, dominant/recessive genes.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Natural selection, artificial selection, evolution, adaptation, resources, reproduction, offspring, breeding, genetic engineering, DNA, cloning, inherit, hereditary, proteins.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Chromosomes, genetic variation, genetic combination, meiosis, mitosis, replications, mutations, gene regulation, allele, RNA sequences, amino acid sequences.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS4-5:
• There is no wild plant that looks like modern corn (soft starchy kernels lined up in a row).
• Farmers isolated wild cabbage plants to create a variety of vegetables, including broccoli and kale. The wild cabbage plants were selected for their different flavors, textures, leaves, and flowers.
• Scientists are currently working to breed sheep that do not burp in order to reduce methane emission.
• Scientists want to breed strong and more resistant bees that won’t be damaged by disease and other parasites.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Generate or construct tables or assemblages of data that document the similarities and differences between traditional and modern gene selection.</td></tr>
</table>

2. Organize and/or arrange data of the success rates of different methods to highlight trends or patterns in genetic modification.
3. Use relationships identified in the data to predict the best gene selection method to use in a given situation.
4. Identify, among distractors, the potential real-world uses of this data.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-LS4-6
Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations to support scientific conclusions and design solutions.</td><td>LS4.C: Adaptation
• Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.</td><td>Cause and Effect
• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.

Content Limits
• Math can include measures of central tendency, basic operations that can be calculated without a calculator, and basic graphical analysis (bar chart, pie chart, scatter plot, box and whisker plot, line chart).
• Students aren’t expected to know the mechanisms of genetic inheritance or mutation.
• Assessment does not include Hardy-Weinberg calculations.
• Assessment does not include other mechanisms of evolution (genetic drift, co-evolution, gene flow, etc.)
• <u>Students do not need to know</u>: Alleles, DNA sequences, anatomical structures, embryonic development, gene frequency, morphology, speciation.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Climate, evolution, inherit, generation, species, genus, reproduction, distribution, ratio .</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Morphology, genetic variance, proliferation, biotic/abiotic.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-LS4-6:
• Some bacteria are killed by a certain antibiotic while other bacteria are immune to it. After the antibiotic is used once, bacteria die. The next time the antibiotic is used, there are many bacteria left.
• The Sandhills in Nebraska used to be covered in dark-colored soil. Most deer mice living in this area had dark-colored fur coats, while others had light-colored fur coats. Over time, the Sandhills were covered in light-colored sand. After many years, the population of deer mice had mostly light-colored fur coats. This will be presented as data.</td></tr>
</table>

<table>
<tr><td></td><td>In the Galapagos Islands, there are finches with thin, small beaks that eat small, soft seeds. There also finches with thick, large beaks that eat larger hard and dry seeds. A drought period in 1977 affected the plant life on the islands, greatly reducing the number of small, soft seeds. The next year, there were far more large-beaked birds than small-beaked birds.</td></tr>
<tr><th colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</th></tr>
<tr><th colspan="2">Task Demands</th></tr>
<tr><td colspan="2">1. Make simple calculations using given data to calculate or estimate changes in the prevalence of specific traits over time.</td></tr>
<tr><td colspan="2">2. Illustrate, graph, or calculate the prevalence of specific traits passed on in observed populations under varying conditions, from given data. The data may be ordinal and the calculations may be representations of trends or propensities.</td></tr>
<tr><td colspan="2">3. Calculate or estimate properties or relationships of the changes in the distribution of traits among a population under varying conditions, based on data from one or more sources.</td></tr>
<tr><td colspan="2">4. Compile, from given information, the data needed for a particular inference about the relationship between changes in the environment and changes in the traits of a population.</td></tr>
<tr><td colspan="2">5. Use mathematical representations and/or computational representations (such as trends, averages, histograms, graphs, spreadsheets) to identify relationships in the data.</td></tr>
<tr><td colspan="2">6. Use mathematical representations and/or computational representations (such as trends, averages, histograms, graphs, spreadsheets) to explain the influence that natural selection has had on the presence of specific traits in a population over time.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and the seasons.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model to describe phenomena.</td><td>ESS1.A The Universe and Its Stars
• Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

ESS1.B Earth and the Solar System
• This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.</td><td>Patterns
• Patterns can be used to identify cause and effect relationships.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of models can be physical, graphical, or conceptual.

Content Limits
• <u>Students do not need to know</u> Earth’s exact tilt; sidereal and synodic periods; umbra and penumbra (the term “shadow” should be used); times of moonrise and moonset; precession; exact dates of equinoxes and solstices (but knowledge of the months in which they occur is reasonable to assess).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Shadow, orbit, axis, planet, satellite, full moon, new moon, half moon</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Perigee, apogee, sidereal period, sidereal month, synodic period, synodic month, umbra, penumbra, precession, equinox, solstice, ecliptic, waxing, waning, gibbous, first quarter moon, last quarter moon</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS1-1:
• When observed from Earth over the course of a month, the appearance of the moon changes.
• A full moon occurs in every calendar month. However, an eclipse of the moon does not occur in every calendar month.
• A new moon occurs in every calendar month. However, a total eclipse of the sun is a rare event.
• In the northern hemisphere, July is a summer month. In the southern hemisphere, July is a winter month.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
</table>

7.	Select or identify from a collection of potential model components, including distractors, components needed for a model that can explain lunar phases, eclipses of the sun, eclipses of the moon, *or* seasons on Earth. Components might include the sun, moon, Earth, solar energy, the moon’s orbital trace, Earth’s orbital trace, the angle of the moon’s orbital trace, the angle of Earth’s orbital trace, Earth’s axis, or the tilt of Earth’s axis.
8.	Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing the causes of lunar phases, eclipses of the sun, eclipses of the moon, *or* seasons on Earth. This does not include labeling a simple diagram of the Earth-sun-moon system.
9.	Describe, select, or identify the relationships among components of a model that can explain lunar phases, eclipses of the sun, eclipses of the moon, *or* seasons on Earth. Components might include the sun, moon, Earth, solar energy, the moon’s orbital trace, Earth’s orbital trace, the angle of the moon’s orbital trace, the angle of Earth’s orbital trace, Earth’s axis, or the tilt of Earth’s axis.
10.	Manipulate the components of a model to demonstrate how the relationships among the sun, the moon, Earth, and solar energy change to result in lunar phases, eclipses of the sun, eclipses of the moon, *or* seasons on Earth. *****
11.	Make predictions about the effects of changes in the relationships among the sun, the moon, Earth, and solar energy as they relate to lunar phases, eclipses of the sun, eclipses of the moon, *or* seasons on Earth. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors. *****
12.	Identify missing components, relationships, or other limitations of a model that can explain lunar phases, eclipses of the sun, eclipses of the moon, *or* seasons on Earth.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS1-2
Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model to describe phenomena.</td><td>ESS1.A: The Universe and Its Stars
• Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B: Earth and the Solar System
• The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
• The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.</td><td>Systems and System Models
• Models can be used to represent systems and the interactions in a system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy, and controls orbital motions within them.
• Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).
• Focus should be on qualitative comparisons, not quantitative.

Content Limits
• Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.
• Assessment does not include specific facts about any planets or moons.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Inertia, force, mass, weight, orbit, names of planets</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Names of specific moons, names of space shuttles, moment of inertia, Kepler's laws of planetary motion, black hole</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS1-2:
• Satellites orbit Earth but can fall out of orbit (Skylab, UART satellite).
• Halley's Comet can be seen as it travels past Earth every 75–76 years.
• Rings are present around some planets.
• Mars has two moons, Phobos and Deimos, which orbit the planet.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Select or identify from a collection of potential model components, including distractors, the components needed for a model that describes the role of gravity in celestial bodies.
2. Assemble or complete, from a collection of potential model components, an illustration, diagram or description that is capable of representing forces and their influences on the motion of celestial bodies and/or man-made objects in orbit. This does not include labeling an existing diagram.
3. Describe, select or identify the relationships among components of a model that can explain the role of gravity in the motions of galaxies and the solar system. Components might include the sun, the moon, Earth, Milky Way galaxy, other planets and their moons.
4. Manipulate the components of a model to demonstrate how the relationships among the sun, the Earth, the moon, planets in the solar system, and galaxies change the resulting gravitational force between/or motions of those bodies.*
5. Make predictions about the effects of changes in mass/distance/how fast an object travels in a given model on other objects in the system. Predictions can be based on manipulating model components, completing illustrations, or selecting from a list including distractors.
6. Identify missing components, relationships, or other limitations of a model that can explain the role of gravity.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS ESS1-3
Analyze and interpret data to determine scale properties of objects in the solar system.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to determine similarities and differences in findings.</td><td>ESS1.B: Earth and the Solar System
• The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.</td><td>Scale, Proportion, and Quantity
• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes and spacecraft to determine similarities and differences among solar system objects.
• Examples of scale properties include the sizes of an object’s layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius.
• Examples of data include statistical information, drawings and photographs, and models.

Content Limits
• Assessment does not include recalling facts about properties of the planets and other solar system bodies.
• <u>Students do not need to know</u>: Facts about properties of the planets and other solar system bodies, scientific notation.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Satellite, terrestrial planet, gas giant, planetary rings, dwarf planet, sun, inner planet, outer planet, comet,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Density, ecliptic, solar wind, interstellar medium, main sequence, synchronous rotation, protostar, protoplanetary disc, accretion.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">The phenomena for this performance expectation are the given data. Samples of phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc).

Some example phenomena for MS-ESS1-3:
• Four of Jupiter’s moons can be clearly seen through a small telescope under low magnification. These moons appear as tiny dots arranged around Jupiter.
• Close-up pictures from the New Horizons mission provided new evidence about the dwarf planet, Pluto, which was not able to be gathered by distant observations and calculations (surface features, scale).
• The sun and the moon appear as approximately the same size in the sky, but the sun is vastly larger than the moon (scale).</td></tr>
</table>

	• Even though the moon is infinitesimally smaller than the sun, the entire sun is blocked from view on Earth during a solar eclipse (scale).

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Make simple calculations using given data to estimate the properties (e.g., mass, surface temp., diameter) and locations of different solar system objects relative to a given reference point/object.
2. Illustrate, graph, or identify relevant features or data that can be used to estimate properties of objects or relationships in our solar system.
3. Calculate, estimate or identify properties of objects or relationships among objects in the solar system, based on data from one or more sources.*
4. Compile, from given information, the data needed for a particular inference about scale or other properties of an object.
5. Given a partial model of objects in the solar system, identify objects or relationships that can be represented in the model or the reasons why they cannot be represented in the model.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS1-4
Construct a scientific explanation based on evidence from rock strata for how the geologic timescale is used to organize Earth’s 4.6-billion-year-old history.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>ESS1.C: The History of Planet Earth
• The geological time scale interpreted from rock strata provides a way to organize Earth’s history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.</td><td>Scale, Proportion and Quantity
• Time, space, and energy phenomena can be observed at various scales, using models to study systems that are too large or too small.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth’s history.
• Example of Earth’s major events could range from being geologically recent (e.g., the most recent glacial period or the earliest fossils of Homo sapiens) to geologically very old (e.g., the formation of Earth or the earliest evidence of life).
• Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant instances of volcanic eruptions.

Content Limits
• Assessment does not include recalling the names of specific periods and epochs or events within them.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Erosion, weathering, ancient, prehistoric, layer, formation, mineral, sedimentary, sediment, metamorphic, volcanic, superposition, cross-cutting, fault, fold, geology, geological</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Radioactive dating, bio-geology, geobiology, relative dating, numerical dating, absolute dating, carbon dating, radiometric dating, igneous, stratigraphy, biostratigraphy, chronostratigraphy, sequence stratigraphy, bed, lamina, paleoenvironment, paleoecology, paleomagnetic</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS1-4:
• A very distinct clay layer tops the Hell Creek Formation in Montana. Below this layer, the Hell Creek is rich in dinosaur fossils; above the layer, no dinosaurs are found.
• The landscape of Cape Cod, Massachusetts, is almost entirely small hills of sand and gravel. However, a hole drilled 500 feet into the ground will hit hard metamorphic rock.
• In Box Canyon in Ouray, Colorado, metamorphic rocks that are standing vertical are capped by sedimentary rocks that are lying flat.
• The St. Peter Sandstone is a very white sandstone rock layer exposed in many places in the midwestern United States. The St. Peter is very uniform in appearance but the rock layer sits on top of different kinds of rocks in the North than it does in Missouri.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize and/or arrange (e.g., using illustrations and/or labels, including taken from or added to, stratigraphic columns and/or geologic maps), or summarize, data/information so as to highlight trends, patterns, or correlations in paleoenvironmental changes, geological events/processes, and/or the appearance or disappearance in the record of specific organisms.*****
2. Generate/construct graphs, tables, or assemblages of illustrations, and/or labels of data/information that document patterns, trends, or correlations in how rock types and included fossils change over geologic time, recording different events and paleo environments. This may include sorting out distractors.*****
3. Use relationships identified in the data/information to hypothesize the relative age of specific rock layers, formations, or fossils, in a stratigraphic column or on a geologic map.*****
4. Identify patterns or evidence in the data/information that support inferences about what the paleoenvironment was like during time intervals represented in a stratigraphic column or on a geologic map.
5. Describe, identify, and/or select information needed to support an explanation.

*denotes those task demands which are deemed appropriate for use in stand-alone item development. 2/3 of these TDs should be combined and used when developing a stand-alone item.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS2-1
Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model to describe the phenomena.</td><td>ESS2.A: Earth’s Materials and Systems
• All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms.</td><td>Stability and Change
• Explanations of stability and change in natural or designed systems can be contructed by examining the changes over time and processes at different scales, including the atomic scale.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the processes of melting, crystallization, weathering, sedimentation, and deformation, which act together to form minerals and rocks through the cycling of Earth’s matter.

Content Limits
• Assessment does not include the identification and naming of minerals.
• <u>Students do not need to know</u>: specific processes of chemical or biogeochemical weathering; rock phase diagrams; mineral stability diagrams; mineral weathering orders; mineral crystallization orders (e.g., Bowen’s Reaction Series); mineral metamorphism orders/temperatures/pressures/stabilities; rock metamorphism zones; specific processes that drive the tectonic engine (e.g., slab pull; ridge push).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Collide, heat conduction, transform, transport, heat transfer, heat radiation, thermal energy, heat convection, precipitation, volcanic eruption, chemical, weathering, erosion, sediment, deposition, rock cycle, ice wedge, fault, fold, igneous rock, metamorphic rock, sedimentary rock, volcanic rock, plate tectonics, crust, mantle, outer core, inner core.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Biogeology, geobiology, geochemistry, biogeochemistry, rock sequence, convection current, mountain building, geochemical cycle, tectonic uplift, accretionary wedge, accretionary prism.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS2-1:
• Lava from an erupting volcano in Hawaii flows across a road. The molten material is so hot that it emits light. Several months later, the material covering the road is a hard, black rock.
• A mountain is capped by metamorphic rock. Many cracks crisscross the rock. Rainwater often fills the fractures, freezing when temperatures drop. Over the years, the fractures become wider.
• An exposure of bedded sandstone has been cut by a plug of igneous rock. Near the edges of the igneous rock, the sandstone is discolored and displays a different texture from the rest of the exposure.
• An exposure of sedimentary rock contains pieces of a metamorphic rock that is exposed several miles away.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include different rock types, processes that change one rock type into another, surface environments on Earth where these processes occur and where different rock types exist, and layers within Earth where these processes occur. Sources of energy (radiation, convection) that drive the cycling (but *not* the creation of) matter should also be included as components.
2. Assemble or complete, from a collection of potential model components, an illustration, virtual representation of a physical model, or flow chart that is capable of representing how energy (radiation, convection) drives processes that cycle (but do *not* create) matter on Earth. This *does not* include labeling an existing diagram.
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to resultin the cycling of Earth’s materials.
4. Make predictions about the effects of changes in the rock cycle. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Given models or diagrams of the rock cycle, identify different rock types and how they change in each scenario OR identify the properties of energy that cause Earth materials to cycle between different rock types.
6. Identify missing components, relationships, or other limitations of the model that can explain the cycling of Earth’s materials.
7. Identify or select the relationships among components of a model that describe the relationship between energy and the cycling of matter that forms different types of rock, or explain the relationship between energy and the cycling of matter that forms different types of rock.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS2-2
Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.</td><td>ESS2.A: Earth's Materials and Systems
• The planet's systems interact over scales that rage from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

ESS2.C: The Roles of Water in Earth's Surface Processes
• Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.</td><td>Scale, Proportion, and Quantity
• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events.
• Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind.
• Emphasis is on geoscience processes that shape local geographic features, where appropriate.

Content Limits
• Students are expected to know all of the components/processes of the rock cycle but not specific rock or mineral names.
• <u>Students do not need to know</u> Endogenic or exogenic systems, specific intervals of the Geological Time Scale by name, specific volcano types (shield, effusive, composite, etc.)/</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Earthquake, volcanic eruptions, core, crust, mantle, pressure, continent, erosion, weathering, magma, lava, igneous, sedimentary, metamorphic, mineral, meteor, crater, plate tectonics, continental drift, subduction zone, divergent boundary, convergent boundary, hot spot, fault, tsunami, hurricane, tornado, fracture, folding, compressing, sea floor spreading, layer, ridge, rock cycle, trench, plateau, slope, landslides, floods, caves</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Endogenic system, exogenic system, radiometric dating, original horizontality, superposition, uniformitarianism, primordial, epoch, eon, period, liquification, Mohorovicic discontinuity (Moho), seismic waves, seismograph, Richter scale, fumaroles, mofettes, solfataras, Caledonian era, Variscan era, Alpine era, massif, graben, monolith, monadnock, nappe system, isostasy, pluton, batholith, stratigraphy, lithification, evaporite, hydrothermal, relief, topography, continental shield, terrain, anticline, syncline, strike-slip fault, horst, orogenesis, tephra, caldera</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS2-2:</td></tr>
</table>

	• A hillside in Oregon experiences an intense rain storm. At the end of the storm, part of the hillside collapses, covering a road with mud and debris. • In Northern Arizona, there is a large circular depression. • In southeastern Pennsylvania, the landscape is dotted with a number of irregular holes that lead to caves. • When viewed from orbit, the Eastern coastline of South America and the Western Coast of Africa look as though they were joined together, similar to a jigsaw puzzle.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how a given process(es) acts to modify Earth's surface in the long term and/or short term. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
3. Identify evidence supporting the inference of causation that is expressed in a causal chain for a process(es) that acts to modify Earth's surface in the long term and/or short term.
4. Use an explanation to predict the effect of the process on Earth's surface, given a change in conditions (e.g., atmospheric, tectonic, geological, hydrologic).
5. Describe, identify, and/or select information needed to support an explanation for how processes affect Earth's surface over the short and/or long term.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS2-3
Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of past plate motions.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to provide evidence for phenomena.</td><td>ESS1.C: The History of Planet Earth
• Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (secondary)

ESS2.B: Plate Tectonics and Large-Scale System Interactions
• Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth’s plates have moved great distances, collided, and spread apart.</td><td>Patterns
• Patterns in rates of change and other numerical relationships can provide information about natural systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of data include similarities of rock and fossil types on different continents, the shapes of continents (including continental shelves), and the locations of ocean structures (such as ridges fracture zones, and trenches).

Content Limits
• Paleomagnetic anomalies in oceanic and continental crust are not assessed.
• <u>Students do not need to know</u>: Specific chemical makeup of the crust, mantle, and core; specific rocks within major categories (e.g., basalt, amphibolite, granite); mineral crystallization orders (e.g., Bowen’s Reaction Series), mineral melt orders.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Crust, mantle, core, convection, density, plate tectonics, earthquake, geosphere, element, continental, upwelling, convection, trench, subduction, ridge, volcanic, sedimentary, fault, extension, volcanic rock, sedimentary rock, metamorphic rock, ridge, hotspot.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Block (as in fault), accretionary wedge, accretionary prism, mantle composition, stress (tectonic), strain (tectonic), normal fault, transform fault, thrust fault, reverse fault, foot wall, hanging wall, felsic, mafic, ultramafic.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS2-3:
• There are volcanoes on all of the Hawaiian islands. But only volcanoes on the southeastern most island, Hawaii, are active today.
• Earthquakes are very commonly felt on the islands of Japan.
• The Atlantic coasts of South America and Africa appear to fit together like two jigsaw puzzle pieces. Identical fossils of certain plants and animals are preserved in rocks found along both coasts.
• Earthquakes are very rare in the State of Florida.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify patterns or evidence in the data that supports conclusions about how the Earth’s plates have moved and interacted with each other (e.g., converged or diverged).*</td></tr>
</table>

2. Use relationships identified in the data to predict the locations of fossils, earthquakes, or volcanoes.
3. Illustrate, graph or identify relevant features or data that can be used to identify past plate motions or estimate the rate of change in tectonic processes.
4. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations.*
5. Compile from given information, the data needed to identify a pattern in the rate of change or evidence of past plate motions.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

Performance Expectation	**MS-ESS2-4** Develop a model to describe how the cycling of water through Earth's systems is driven by energy from the sun, gravitational forces, and density.		
Dimensions	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. • Global movements of water and its changes in form are propelled by sunlight and gravity.	**Energy and Matter** • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
Clarifications and Content Limits	**Clarification Statements** • Examples of models can be conceptual or physical. • Content emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. • Practice emphasis is on developing a model and being able to explain reasoning behind choices made relative to the developing or changing of a model. While a few interactions can be about using the model, the focus should not be on using the model or designing an experiment using the model. Any stand-alone items written to this PE should be centered on the development of models. **Content Limits** • A quantitative understanding of the latent heats of vaporization and fusion is not assessed. • Students do not need to know: o Cloud types o Types of aquifers and components of aquifers o Concepts of subsurface water flow and transmissivity (e.g., permeability/porosity of the substrate and interactions with fluids; behaviors of subsurface fluids under confinement (both quantitatively and qualitatively).		
Science Vocabulary Students are Expected to Know	Precipitation, transpiration, evaporation, condensation, crystallization, density, runoff, temperature, air pressure, particle, atmosphere		
Science Vocabulary Students are Not Expected to Know	Hyporheic zone, aquifer, aquitard, aquiclude, subsurface flow, sublimation, vadose zone, unsaturated zone, water table, phreatic surface, capillary fringe, saturated zone, phreatic zone, drainage basin, watershed, porosity, permeability, transmissivity, recharge, recharge area, discharge, discharge area, potentiometric surface, hydraulic head, lithosphere, biosphere, hydrosphere, cryosphere		
Phenomena			
Context/ Phenomena	Some example phenomena for MS-ESS2-4: • When driving over a bridge on a cool morning, you see fog over the river but not over the land. • Morning fog and mist soon disappears after the sun rises on a clear day. • The Blue Mountains have snow that melts (eventually) into the Columbia River to the John Day Dam • In the Iowa cornfields in the summer, a dense dome of humidity forms over the cornfields.		

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components including distractors, the components needed to model the model of evaporation, condensation, transpiration, precipitation or other behaviors of water molecules during the water cycle.	
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing the phenomenon. This does not include labeling an existing diagram.*	
3. Manipulate the components of a model to demonstrate the effects those adjustments would have on the behavior of water in the water molecules in the water cycle.*	
4. Make predictions about the effects of changes to the parts of the model. Predictions can be based on manipulating model components, completing illustrations, or selecting from a list with distractors.	
5. Identify missing components, relationships, or other limitations of the model.	
6. Describe, select, or identify the relationships among components of a model that describe or explains the phenomenon.	
7. Identify, describe or explain reasons for choosing components of a model of the water cycle.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.</td><td>ESS2.C: The Roles of Water in Earth’s Surface Processes
• The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.D: Weather and Climate
• Because these patterns are so complex, weather can only be predicted probabilistically.</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide.
• Emphasis is on how weather can be predicted within probabilistic ranges.
• Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as condensation).

Content Limits
• Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.
• Weather incidents internal to air masses are excluded because the focus is on the interfaces between large scale air masses.
• <u>Students do not need to know</u>: Names of the various types of clouds, weather symbols used on weather maps, weather symbols used on reports from weather stations. A legend will be included on weather maps.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Density, temperature, pressure, humidity, precipitation, wind speed, wind direction, air mass, cold/warm front, condensation, evaporation, latitude, altitude, flow, thermometer, barometer, anemometer, dew point, stationary front, occluded front, warm front, cold front</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Horse latitudes, Tropic of Capricorn, Tropic of Cancer, cyclone, anticyclone, isobar, isotherm, pressure gradient, Coriolis force*, hygrometer and psychrometer (humidity meters), jet stream,
*Coriolis force IS covered in PE MS-ESS2-6, however.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS2-5:
• One fall day starts out warm and fairly still. The wind picks up and the temperature drops and it begins to rain.</td></tr>
</table>

	• The flag outside a school has been resting against the flagpole, unmoving all morning. In the early afternoon, it starts flapping in the wind. At sunset, rain begins. • Fall days were chilly, then the temperature warmed up for a few days. • A tornado formed in the Pacific Ocean near Oregon.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Evaluate the sufficiency and limitations of data collected to explain the phenomenon.
2. Identify the outcome data that should be collected in an investigation of the interactions of air masses and the resulting changes in weather conditions.
3. Make and/or record observations about the interactions of air masses and/or the relationships between those interactions and patterns of weather in a particular location.
4. Describe, illustrate, or select tools, locations, and/or methods to use in investigations of phenomena related to interactions of air masses. This should show how or where measurements will be taken.
5. Identify, select, or describe the relevance of particular data or sources relevant to the process of weather forecasting.
6. Predict the effects of given changes in the air masses' interactions on subsequent weather.
7. Identify or specify inferences supported by data collected.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS ESS2-6
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model to describe phenomena.</td><td>ESS2.C: The Roles of Water in Earth's Surface Processes
• Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D: Weather and Climate
• Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
• The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.</td><td>Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution.
• Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis Effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis Effect and the outlines of continents.
• Examples of models can be diagrams, maps and globes, or digital representations.

Content Limits
• Assessment does not include the dynamics of the Coriolis effect.
• <u>Students do not need to know</u>: names of specific winds, different cloud types (cumulus, cirrus etc.), names of specific ocean currents, or perform any quantitative analyses based on the Coriolis Effect, mathematical calculations beyond trends, or measurements of central tendency.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Climate, temperature, atmospheric pressure, density, current, latitude, altitude, Coriolis effect, convection, condensation, precipitation, cloud, water cycle, air mass circulation, vegetation, latitude, longitude, rain shadow.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Trade winds, Easterlies, Westerlies, cumulus, cirrus, or other cloud names, Gulf Stream, Labrador, UV rays, horse latitudes, Tropic of Cancer, Tropic of Capricorn.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS2-6:</td></tr>
</table>

	• In December 2010, Gary, Indiana, on the southeast shores of Lake Michigan, had approximately 30 inches of snow over a three-day period, whereas Chicago, Illinois, 30 miles away, received barely any snow. • Onshore and offshore breezes—in the morning, the breeze comes in from the ocean. At night, the breeze is blowing in the opposite direction. • Wind storms in the Sahara become hurricanes that affect the east coast of North America and the Caribbean, but not the coast of South America. • The Westerlies vs. The Easterlies and the trade winds—why are these wind patterns banded as you move north from the equator?

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Select or identify from a collection of potential model components, including distractors, components needed for a model that can explain the effect of unequal heating of Earth’s surface. Components might include oceans, land forms, wind currents, ocean currents, energy flows, upwelling, downwelling, water temperature, air temperature, and salinity.
2. Assemble or complete an illustration or flow chart that is capable of representing the effect of unequal heating of Earth’s systems on atmospheric and oceanic circulation. Key components of the model might include: oceans, land forms, wind current, ocean current, energy flows, upwelling, downwelling, water temperature, and salinity.
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in a phenomenon.
4. Make predictions about the effects of changes in temperature on a phenomenon. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors. Make predictions about the effects of changes in water temperature or density, distance from the lake, location, etc.
5. Identify missing components, relationships, or other limitations of a model.
6. Describe, select, or identify the relationships among components of a model that explain the effect of unequal heating of Earth’s systems on atmospheric and oceanic circulation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS3-1
Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>ESS3.A: Natural Resources
• Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.</td><td>Cause and Effect
• Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans.
• Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (location of the burial of organic marine sediments and subsequent geologic traps), metal ores (location of past volcanic and hydrothermal activity associated with subduction zones), and soil (location of active weathering and/or deposition of rock).</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Agricultural, biosphere, conservation, consumption, deposition, distribution, efficient, energy source, geologic trap, hydrothermal, impact, interdependence, marine sediment, metal ore, , organic, petroleum, regulation, renewable energy, subduction zone.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Bitumen, harvesting of resources, viscous, natural gas, oil shale, sustainability, tar sand, extract, irreversible.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS3-1:
• Large surface deposits of sand and gravel are much more common in Massachusetts than they are in Virginia.
• Diamonds are found on the ground in a State Park in southwestern Arkansas.
• Bauxite, an Aluminum ore, and fossil tree roots are found in an exposure in Queensland, Australia.
• A well is drilled and water is discovered near Colorado Springs, CO. Ten miles to the Southwest, another well is drilled to the same depth and no water is discovered.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
</table>

2. Express or complete a causal chain explaining that the uneven distribution of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Use an explanation to predict the distribution of Earth's mineral, energy, or groundwater resources, given a change in current geoscience processes.
5. Describe, identify, and/or select information needed to support an explanation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS3-2
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze and interpret data to determine similarities and differences in findings.</td><td>ESS3.B: Natural Hazards
• Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events.</td><td>Patterns
• Graphs, charts, and images can be used to identify patterns in data.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable.
• Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods).
• Examples of data can include the locations, magnitudes, and frequencies of the natural hazards.
• Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).

Content Limits
• Analysis may include recognizing patterns in data, identifying periodicity, straightforward mathematical comparisons (more, less, faster, slower), examining trends, looking for differences in tabular data, qualitative spatial analysis (e.g., looking at fault lines), recognizing trends and patterns. May include drawing lines of best fit and extrapolating from those lines.
• Analysis should not include regression analysis or calculating correlations.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Air mass, air mass circulation, altitude, atmospheric circulation, biosphere, carbon dioxide, climatic pattern, condensation, convection cycle, Coriolis effect, cyclical, density, distribution, geography, geological, gradual, intensity, land distribution, latitude, longitude, ocean circulation, orbit, orientation, pressure, redistribute, salinity, store, tectonic, tectonic cycle, tilt, transfer, unequal heating of air, unequal heating of land masses, unequal heating of oceans, weather map, catastrophic, debris, frequency, geologic, interdependent, magnitude, mass wasting, natural process, reservoir, satellite.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Concentration, electromagnetic radiation, radiation, sea level.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">For this performance expectation, the phenomena are sets of data. Those are the observed facts that the kids will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed.

Patterns that describe the data sets for MS-ESS3-2:</td></tr>
</table>

	• A sequence of maps illustrates temperature patterns and occurrence of tornados over the course of the year (to identify variations of tornado risk across regions and also to identify more proximate predictors of tornados). • A sequence of maps illustrates temperature and humidity patterns and occurrence of hurricanes over the course of the year (to identify variations of hurricane risk across regions and also to identify more proximate predictors of hurricanes). • Temperature and humidity patterns in the Pacific Ocean can be correlated to the snow pack on Mt. Hood. • A map of average snowfall in the Great Lakes region shows more snow has fallen in locations nearer to the lakes. Data include surface temperatures, water temperature, wind patterns and snowfall.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize/Arrange data to highlight patterns, trends, or correlations between natural hazards and geologic/atmospheric events that occur before a natural hazard.*
2. Tabulate/Graph data to highlight patterns, trends, or correlations between natural hazards and geologic/atmospheric events that occur before a natural hazard.*
3. Use relationships identified in the data to predict natural hazards.
4. Illustrate or describe patterns over time that can be used to predict natural hazards.*
5. Identify human and societal responses designed to mitigate catastrophic natural hazards.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS3-3
Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific principles to design an object, tool, process or system.</td><td>ESS3.C: Human Impacts on Earths Systems
• Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
• Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts of Earth unless the activities and technologies involved are engineered otherwise.</td><td>Cause and Effect
• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact.
• Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the constructions of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as air, water, or land).

Content Limits
• Students will not describe the relationship between natural resources and sustainability</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Wetland, agriculture, development, fertile, groundwater, industry, material world, mineral, river delta, aquifer, economic, land usage, levee, water usage, consumption, land use management, conservation, preservation</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Anthropogenic changes, urban development, biomass, degradation, destabilize, geoengineering, ozone, pollutant, sea level, stabilize, waste management, harvesting of resources, cost-benefit</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering performance expectations are built around meaningful design problems rather than phenomena.

Some example design problems for MS-ESS3-3:
• Nurdles are small plastic pellets, smaller than a pea. Billions of them are used in creating plastic products. Many fall out of the truck or ship container that they are transported in and end up in oceans where they are mistaken as food by marine animals.
• Glen Canyon Dam is located on the Arizona and behind it sits Lake Powell the second largest reservoir in the United States. Glen Canyon Dam holds back sediment that would naturally replenish downstream ecosystems. The sediment that is trapped behind the dam is filling Lake Powell at a rate of roughly 100 million tons of sediment a year, decreasing the dam's ability to store water.</td></tr>
</table>

	• Farmers in Iowa plow their fields in the spring in order to break up the thick soil and disrupt weeds from growing. The practice of plowing however, causes farmers to lose valuable top soil due to wind erosion. • In the central North Pacific Ocean there is what is described as a great garbage patch. This large area has high concentrations of plastics, fishing nets, and other debris. This debris is sometimes mistaken as food by marine animals.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Identify or assemble from a collection, including distractors, the relevant aspects of human impact on the environment that given design solutions, if implemented, will resolve/improve.	
2. Using the given information about human impact on the environment, select or identify the criteria against which the device or solution should be judged.	
3. Using given information about human impact on the environment, select or identify constraints that the device or solution must meet.	
4. Using given data, propose/illustrate/assemble a potential device (prototype) or solution to monitor and/or minimize human impact on the environment.	
5. Using a simulator, test a proposed prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS3-4
Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.</td><td>ESS3.C: Human Impacts on Earth Systems
• Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise.</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources such as fresh water, minerals, and energy sources.
• Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.

Content Limits
• Assessment is limited to one form of consumption and its associated impacts.
• <u>Students do not need to know</u>: mechanisms or details about interior geological processes, quantities and types of pollution released, changes to biomass and species diversity, or changes in land surface use.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Conservation, recycling, perishable, synthetic, manufactured, rivers, lakes, groundwater, fertile, delta, fossil fuels, pollution, composition, glacier, mass, volume, concentration.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Tar sands, oil shales, agricultural efficiency, urban planning, aesthetics, biomass, glacial ice volumes, hydrosphere, cryosphere, geosphere, acidification, empirical evidence, polar caps.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS3-4:
• Lake Urmia in Iran was once the nation's largest lake. Today, the lake is 5% as large as it used to be.
• In 1990, much of the tropical rain forests on the Hainan Island were clear-cut to obtain wood, and to create space for plantations. Today, the forests are still smaller and less developed than they were before 1990.
• A coal power plant in Martins Lake, Texas, releases huge clouds of gas into the air every day.
• The open-pit copper mine Ok Tedi Mine in Papua, New Guinea, releases its drainage nearby. Downstream, the rivers turned orange and the fish died.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information.
2. Predict outcomes when properties or amounts of consumption are changed, given the inferred cause and effect relationships.
3. Describe, identify, and/or select information needed to support an explanation of how increases in human population and per-capita consumption of natural resources impact Earth's systems.
4. Identify patterns or evidence in the data that support conclusions about the relationship between per capita consumption and limited natural resources.*
5. Using evidence, explain the relationship between per capita consumption and limited natural resources.*
6. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">MS-ESS3-5
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Ask questions to identify and clarify evidence of an argument.</td><td>ESS3.D: Global Climate Change
• Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as the understanding of human behavior and on applying that knowledge wisely in decisions and activities.</td><td>Stability and Change
• Stability might be disturbed either by sudden events or gradual changes that accumulate over time.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of factors include human activities (such as fossil-fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity).
• Examples of evidence can include tables, graphs, and maps of global and regional temperatures; atmospheric levels of gases such as carbon dioxide and methane; and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Force, rotation, intensity, physical change, glacial, weather condition, natural resource, natural process, catastrophic, cycle, atmospheric composition, environmental, pollution, societal, renewable resource, nonrenewable, oil, absorb.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Climactic pattern, cyclical, concentration, magnitude, destabilize, consumption, civilization, degradation, pollutant, sea level, stable, natural gas.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for MS-ESS3-5:
• A region in the Saint Elias Mountains in Alaska used to be covered by Plateau Glacier. It is now populated with thick vegetation and lake.
• On December 14th, 2016, the Deely Power Plant was operating. Its chimney emitted a large cloud of white smoke.
• The Solomon Islands are a group of small islands located in the Pacific Ocean. Five of these islands disappeared in 2016.
• Mount Etna, one of the world's most active volcanoes, erupted in May 2016, delivering large plumes of smoke that filled the horizon.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">6. Organize and/or arrange (e.g., using illustrations and/or labels) or summarize data to highlight trends, patterns, or correlations.</td></tr>
<tr><td colspan="4">7. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations relating to climate change. This may include sorting out distractors.</td></tr>
</table>

8. Express or complete a causal chain explaining the effects that climate change has on the environment. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram or completing cause-and-effect chains.
9. Compile, from given information, the particular data needed for a particular inference about the relationship between greenhouse gas emissions and rising global temperatures. This can include sorting out the relevant data from the given information.
10. Describe, select, or identify the relationships among components of a model that describe the mechanism of rising global temperatures, or explain the consequences of rising global temperatures.
11. Select, from a list of potential hypotheses including distractors, either the testable hypothesis from untestable hypotheses or the best hypothesis to clarify evidence relating to climate change.
12. Construct or assemble a valid hypothesis that clarifies evidence relating to climate change.
13. Select from a list of questions, including distractors, about the relationships among the data that either support or contradict a hypothesis or to clarify data that describe the mechanism of rising global temperatures, or explain the consequences of rising global temperatures.
14. Ask questions to obtain or clarify information related to the rise of global temperatures in the past century.

Specifications for High School

Introduction

This document presents *cluster specifications* for use with the Next Generation Science Standards (NGSS). These standards are based on the Framework for K-12 Science Education. The present document is not intended to replace the standards, but rather to present guidelines for the development of items and item clusters used to measure those standards.

The remainder of this section provides a very brief introduction to the standards and the framework, an overview of the design and intent of the item clusters, and a description of the cluster specifications that follow. The bulk of the document is composed of cluster specifications, organized by grade and standard.

Background on the framework and standards

The Framework for K-12 Science Education are organized around three core dimensions of scientific understanding. The standards are derived from these same dimensions:

- Disciplinary Core Ideas: The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.
- Science and Engineering Practices: The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.
- Cross-Cutting Concepts: These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.
- There is substantial overlap between and among the three dimensions. For example, the cross-cutting concepts are echoed in many of the disciplinary core ideas. The core ideas are often closely intertwined with the practices. This overlap reflects the nature of science itself. For example, we often come to understand and communicate causal relationships by employing models to make sense of observations. Even within a dimension, overlap exists. Quantifying characteristics of phenomena is important in developing an understanding of them, so employing computational and mathematical thinking in the construction and use of models is a very common scientific practice, and one of the cross-cutting concepts suggests that scientists often infer causality by observing patterns. In short, the dimensions are not orthogonal.

The framework envisions effective science education as occurring at the intersection of these interwoven dimensions: students learn science by doing science—applying the practices through the lens of the cross-cutting concepts to investigate phenomena that relate to the content of the disciplinary core ideas.

Item clusters

Each item cluster is designed to engage the examinee in a grade-appropriate, meaningful scientific activity aligned to a specific standard.

Each cluster begins with a phenomenon, an observable fact or design problem that engages student interest and can be explained, modeled, investigated, or designed using the knowledge and skill described by the standard in question.

What it means to be observable varies across practices. For example, a phenomenon for a performance expectation exercising the a*nalyze data* practice may be observable through regularities in a data set, while standards related to the *development and use of models* might be something that can be watched, seen, felt, smelled, or heard.
What it means to be observable also varies across grade levels. For example, elementary-level phenomena are very concrete and directly observable. At the high school level, an observation of the natural world may be more abstract--for example, "observing" changes in the chemical composition of cells through the observation of macroscopic results of those changes on organism physiology, or through the measurement of system- or organ-level indications.
Content limits refine the intent of the performance expectations and provide limits on what may be asked of items in the cluster to structure the student activity. The content limits also reflect the disciplinary core ideas learning progressions that are present in the K-12 Framework for Science Education.

The task or goal should be explicitly stated in the stimulus or the first item in the cluster: statements such as "In the questions that follow, you will develop a model that will allow you to identify moons of Jupiter," or "In the questions below, you will complete a model to describe the processes that lead to the steam coming out of the teapot."
Whereas item clusters have been described elsewhere as "scaffolded," they are better described as providing structure to the task. For example, some clusters begin with students summarizing data to discover patterns that may have explanatory value. Depending on the grade level and nature of the standard, items may provide complete table shells or labeled graphs to be drawn, or may require the student to choose what to tabulate or graph. Subsequent items may ask the student to note patterns in the tabulated or graphed data and draw on domain content knowledge to posit explanations for the patterns.
These guidelines for clusters do not appear separately in the specifications. Rather, they apply to all clusters.

Structure of the cluster specifications

The item cluster specifications are designed to guide the work of item writers and the review of item clusters by stakeholders.
Each item cluster has the following elements:

- The text of the performance expectations, including the practice, core idea, and cross-cutting concept.
- Content limits, which refine the intent of the performance expectations and provide limits of what may be asked of examinees. For example, they may identify the specific formulae that students are expected to know or not know.
- Vocabulary, which identifies the relevant technical words that students are expected to know, and related words that they are explicitly not expected to know. The vocabulary included in both sections (Students are Expected to Know and Students Are Not Expected to Know) were developed after the reviews of standards at the current/preceding grades, the original NGSS documentation, and item writer reference documentation including the Children Writers' Word Book and ED Core Vocabularies in Reading, Mathematics, Science and Social Studies. All vocabulary included in the specifications was reviewed and edited by teacher committees during the specification reviews by states. Of course, the latter category should not be considered exhaustive, since the boundaries of relevance are ambiguous, and the list is limited by the imagination of the writers/reviewers.
- Sample phenomena, which provide some examples of the sort of phenomena that would support effective item clusters related to the standard in question. In general, these should be guideposts, and item writers should seek comparable phenomena, rather than drawing on those within the documents. Novelty is valued when applying scientific practices.
- Task demands comprise the heart of the specifications. These statements identify the types of items and activities that item writers should use, and each item written should be clearly linked to one or more of the demands. The verbs in the demands (e.g., *select, identify, illustrate, describe*) provide guidance on the types of interactions that item writers might employ to elicit the student response. We avoid explicitly identifying interaction types or item formats to accommodate future innovations and to avoid discouraging imaginative

work by the item writers. All task demands should be aligned to a minimum of one of the three dimensions (DCI, SEP and CCCs) and across task demands within a cluster, all three dimensions must be addressed.

- For each cluster we present, the printed documentation includes the cluster, the task demands represented by each item, and its linkage to the content, practice and cross-cutting concept identified in the performance expectation.

Item cluster specifications follow, organized by domain and standard.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model to predict the relationships between systems or between components of a system.</td><td>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.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment is limited to main group elements.
• Assessment does not include quantitative understanding of ionization energy beyond relative trends.
• <u>Students do not need to know:</u> Properties of individual elements, names of groups, anomalous electron configurations (Chromium and Copper)</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Proton, electron, neutron, valence shell, filled shell, ion, cation, anion, metal, nonmetal, metalloid, group, period, family, pure substance, atomic number, atomic symbol, atomic weight, ionic bond, covalent bond, s, p, d, f orbitals, electron configuration, core electrons, nucleus, single, double, triple bond(s), molar mass, atomic radius, electronegativity,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Oxidation state, diatomic, polyatomic ions, empirical formulas, molecular formulas, quantum, photon, Heisenberg Uncertainty Principle, Hund’s Rule, Pauli Exclusion Principle</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-1:
• Potassium chloride (KCl) tastes similar to table salt (sodium chloride ($NaCl$)).
• Balloons are filled with helium gas instead of hydrogen gas.
• Scientists work with silicate substrates in chambers filled with Argon instead of air.
• Diamond, graphene, and fullerene are different molecules/materials that are only made of carbon.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of periodic table components (periods, groups, etc.), including distractors, the components needed to model the phenomenon.</td></tr>
<tr><td colspan="4">2. Make predictions about the properties of elements based on the number of valence electrons. Predictions can be made by completing illustrations or selecting from lists with distractors.</td></tr>
</table>

3. Identify missing components, relationships, or other limitations of the model. (Hydrogen similar to Alkali metals, one valence electron, and Halogens, missing only one valence electron).
4. Describe, select, or identify the relationships among components of the periodic table that describe the properties of valence electrons, or explains the properties of elements.

<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>Dimensions</td><td>Constructing explanations and designing solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.

Content Limits
• Assessment is limited to chemical reactions involving main group elements and combustion reactions.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Reversible, atomic weight, chemical bond, electron sharing, ion, outer electron state, energy level, electron transfer, concentration, equilibrium, endothermic, exothermic, stable, combustion, yield(s), flammability, octet</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Molecular orbital diagram, multiplicity, antibonding orbitals, rearrangement, by-product, oxidation-reduction reaction, decomposition, single replacement reaction, double replacement reaction, synthesis reaction, precipitate</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-2:
• A coal oven without proper ventilation produces billows of dark smoke.
• Two metals are placed in water. One bubbles and fizzes, while the other gives off a yellow flame and white smoke.
• Carlsbad Caverns is a large cave in New Mexico. Inside, large pointy structures appear to be growing from the ceiling.
• A shiny metallic solid is combined with a green gas, resulting in a white crystalline solid.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

15. Use relationships identified in the data to predict properties of other chemical compounds, elements, and/or mixtures.
16. Identify patterns or evidence in the data that supports inferences about the properties of other chemical compounds/elements/mixtures.
17. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations.
18. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
19. Use an explanation to predict the properties of other chemical compounds/elements/mixtures given a change in reagents or conditions.
20. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations relating to the periodic table. This may include sorting out distractors.
21. Select, articulate, or construct an explanation about a chemical reaction. This may include identifying/selecting the products of the reaction as part of an explanation.

Performance Expectation	**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.		
Dimensions	**Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**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.	**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.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on understanding the strength 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. **Content Limits** • Assessment does not include Raoult's law, nor calculations of vapor pressure.		
Science Vocabulary Students Are Expected to Know	Nucleus, proton, electron, neutron, electron cloud, intramolecular force, covalent bond, ionic bond, intermolecular force, electrostatic force, electronegativity, electron distribution, polarity, temporary polarity, permanent polarity, polarize, surface area, atomic radius, atomic weight, atomic mass, solute, solvent, dissolve.		
Science Vocabulary Students Are Not Expected to Know	Dipole, induced dipole, dipole moment, delta, Coulomb's law, dipole-dipole, London forces, Van der Waals forces, ion-dipole, hydrogen bonding, pi-electron cloud, pi stacking, colligative properties, electron shielding.		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS1-3: • Two neighbors apply different salt treatments to their driveways the night before a freeze is predicted. The next morning, no ice formed on one of their driveways. However, the other driveway was covered with a thin layer of ice. • A chef makes salad dressing by completely mixing oil, water, and vinegar in a large container. Afterwards, he pours the mixed dressing from the large container into individual containers and places one container on each of the restaurant's tables before leaving for the night. In the morning, the chef finds a layer of oil floating on top of a liquid layer in each of the containers on the tables. • After working with painting oils, an artist finds that she must wash her hands with soap and water to remove the oil from her hands, as rinsing with water alone does not remove the oil.		

	• A glass is completely filled with water. When coins are added to the full glass of water, the surface of the water rises above the rim of the glass without spilling.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify from a list, including distractors, the materials/tools needed for an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
2. Identify the outcome data that should be collected in an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
3. Evaluate the sufficiency and limitations of collected data about the physical properties/interactions of substances at the bulk scale to explain the phenomenon.
4. Make and/or record observations about the physical properties/interactions of substances at the bulk scale that provide evidence to support inferences about the relative strengths of the electrostatic attractions between the particles of those substances.
5. Interpret, summarize, and/or communicate the data from an investigation concerning the physical properties/interactions of substances at the bulk scale.
6. Explain or describe the causal processes that lead to the observed data.
7. Select, describe, or illustrate a prediction concerning the physical properties of or interactions between additional substance(s), and/or the strength of electrostatic attractions between the particles of additional substance(s), made by applying the findings from an investigation.

<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>Dimensions</td><td>Developing and Using Models
• 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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawing and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.

Content Limits
• Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Transfer, heat energy, atomic arrangement, stored energy, conversion, bond energy, release of energy, endothermic, exothermic</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Recombination of chemical elements, stable, chemical system, chemical reaction rate</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-4:
• Scientists gather samples of rock from the ocean floor. One sample looks and feels like ice, but burns and produces a flame when ignited.
• Wet cement is left sitting outside. After one day, the cement becomes hard and stiff.
• A temperature of a sample of tin is lowered from room temperature to 0 °C. The tin changes color from silver to gray, becomes brittle, and starts developing cracks on its surface.
• Baking soda is added to a container of citric acid at room temperature. The resulting solution becomes cold, and returns back to room temperature after 2 minutes.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include models of bonds breaking and forming, heat absorbed or released, or aspects of a chemical reaction.
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing a release or absorption of energy from a chemical reaction. This does not include labeling an existing diagram.
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
4. Make predictions about the effects of changes in bond energies. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Describe, select, or identify the relationships among components of a model that describes a release or absorption in energy, or explains why a release or absorption in energy is dependent on total bond energy.

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	**Constructing Explanations and Designing Solutions** • 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.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules. **Content Limits** • 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.		
Science Vocabulary Students are Expected to Know	Stored energy, heat energy, atomic arrangement, conversion, bond energy, endothermic, exothermic, concentration, reaction rate, activation energy, catalyst, enzyme, equilibrium		
Science Vocabulary Students are Not Expected to Know	Recombination of chemical elements, stable, chemical system, rate laws, Le Chatelier’s principle, rate constant, zero order reactions, first order reactions, stepwise reactions, rate-determining step, steady state, half-life, free radicals, entropy, Gibb’s free energy		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS1-5: • One bowl of bread dough was set aside to rise in a cool area of a kitchen. Another was set aside to rise near the warm oven. The dough near the oven rose faster than the dough set in the cool area. • A marble stone was exposed to rain water with different acidities on two different spots on the stone. After some time, one spot on the stone was more eroded than the other. • Cookies baked in an oven set to 170°C took longer to bake than cookies baked in an oven set to 220°C. • Inside a fume hood, an adult wearing gloves and goggles carefully added hydrochloric acid to a solution containing sodium thiosulfate ($Na_2S_2O_3$) and a yellow solid appeared in the test tube. Then, dilute hydrochloric acid was added to a second test tube of $Na_2S_2O_3$, and the yellow solid took longer to appear.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			

1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how temperature and/or concentration changes can change the rate of a chemical reaction. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
3. Identify patterns or evidence in the data that supports inferences about the effects of changing temperature or concentration on the rate at which a chemical reaction occurs.
4. Use an explanation to predict the changes in the rate of other chemical reactions, given a change in reagents or conditions, including temperature and concentration of reactants.
5. Select, articulate, or construct an explanation about a chemical reaction. This may include identifying/selecting the products of the reaction as part of an explanation.*
6. Use evidence to construct an explanation of how changing temperature or concentration of reacting particles on the rate of a reaction.*

*denotes task demands that are approved for use with standalones.

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	**Constructing Explanations and Designing Solutions** • 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.
Clarifications and Content Limits	**Clarification Statements** • 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 **Content Limits** • Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.		
Science Vocabulary Students are Expected to Know	Surface area of reactants, dynamic, thermal energy, heat energy, atomic arrangement, equilibrium, bond energy, endothermic, exothermic, catalyst, chemical bond, mole, element, compound, concentration, Le Chatelier's principle		
Science Vocabulary Students are Not Expected to Know	Recombination of chemical elements, stable, chemical system, chemical reaction rate		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS1-6: • Leftover food left on the counter overnight spoils more quickly than food stored in the refrigerator at 1.6℃. • Several drops of hydrochloric acid were added to an orange mixture of water and potassium dichromate (K_2CrO_7). The mixture turned yellow. • In the 1970s scientists observed that the concentration of ozone (O_3) in the upper atmosphere began decreasing. • A bottle of carbonated soda appears to have fewer bubbles before it is opened than after it is opened.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			

Task Demands
9. Express or complete a causal chain explaining the chemical processes that resulted in a shift in equilibrium. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
10. Describe, identify, and/or select evidence supporting the inference of causation that is expressed in a causal chain and/or an explanation of the processes that cause the observed results.
11. Predict the direction or the relative magnitude of a change in equilibrium of a chemical system, given a change in the amount/concentration of chemical substances in the system, the temperature of the substances in the system, and/or the amount of pressure applied to the substances in a system.
12. Identify or assemble from a collection, including distractors, of the relevant aspects of the problem that a given design solution, if implemented, will resolve or improve.
13. Using the given information, select or identify the criteria against which the solution should be judged.
14. Using given data, propose, illustrate, or assemble a potential solution that would shift equilibrium to favor the products of a chemical reaction.
15. Using a simulator, test a proposed solution and evaluate the outcomes, potentially including proposing and testing modifications to the solution.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS1-7
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• 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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include complex chemical reactions.
• <u>Students do not need to know:</u> Properties of individual elements</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">mole, molar ratio, molar mass, limiting reactant, excess reactant, yield(s), theoretical yield, actual yield, concentration, conversion, reversible, ion, cation, anion, metal, nonmetal, metalloid, pure substance, atomic number, atomic symbol, atomic weight, ionic bond, covalent bond</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Dimensional analysis, stoichiometry, (dynamic) equilibrium, La Chatlier’s Principle, oxidation state, diatomic, polyatomic ion, empirical formula, by-product, oxidation-reduction reaction, decomposition, single replacement reaction, double replacement reaction, synthesis reaction, combustion reaction, precipitate, solvent, solute, reaction rate, recombination of chemical elements, stable</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-7:
• Methane gas flows into a Bunsen burner. When a spark is applied, methane gas reacts with oxygen in the air to produce a blue flame. The flame gets larger as the oxygen valve is turned to allow more oxygen to mix with methane.
• Different masses of baking soda are placed inside three balloons of the same size. Three grams of baking soda is added to the first balloon, four grams is added to the second balloon, and five grams is added to the third balloon. Each balloon is placed on top of a bottle containing 200mL of vinegar, with care that no baking soda is lost from the balloons. When the baking soda inside each balloon drops into the vinegar, the balloons eventually inflate. The balloon containing 4g of baking soda inflates to a larger size than the balloon containing 3g. However, the balloon containing 5g of baking soda inflates to the same size as the balloon containing 4g.
• When colorless solutions of sodium sulfate (Na_2SO_4) and strontium nitrate ($Sr(NO_3)2$) are mixed, a white solid forms. Equal masses of the white solid are recovered when 30.0 mL of 0.10 M Na_2SO_4 solution is added to 70.0 mL of 0.20 M $Sr(NO_3)_2$ solution and when 30.0 mL of 0.20 M Na_2SO4 solution is added to 70.0 ml of 0.20 M $Sr(NO_3)_2$ solution.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Make simple calculations using given data to estimate, calculate, and/or predict the masses of substances involved in a chemical reaction. These calculations may include the optimal ratio of reactants for a chemical reaction, mass of the limiting reactant, the mass of the excess reactant, theoretical yield, and actual yield.	
2. Illustrate, graph, describe, and/or identify the proportional relationships between substances involved in a chemical reaction that can be used to calculate or estimate the masses of atoms in the reactants and the products of that chemical reaction.	
3. Describe and predict simple chemical reactions in terms of mass, using proportional relationships among the substances involved in a chemical reaction.	
4. Compile, from given information, the particular data needed for a particular inference about the amounts of matter within a chemical system. This can include sorting out the relevant data from the given information.	

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	**Developing and Using Models** • 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.
Clarifications and Content Limits	**Clarification Statements** • 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. **Content Limits** • Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.		
Science Vocabulary Students are Expected to Know	Absorption, transformation, nuclear reaction, nucleus, decay rate, fission, fusion, neutron, nuclear mass, unstable, half-life, radioactive, radiation, alpha particle, alpha decay, beta particle, beta emission, gamma radiation, atomic number, atomic mass, proton, radioactive decay		
Science Vocabulary Students are Not Expected to Know	Nucleon(s), radioisotopes, positron, positron emission, electron capture, radioactive series, nuclear disintegration series, magic numbers, nuclear transmutations, particle accelerators, transuranium elements, radiometric dating, becquerel (Bq) unit, curie (Ci) unit, Geiger counter, radiotracer, critical mass, supercritical mass, nuclear reactor, ionizing radiation, nonionizing radiation, target nucleus, bombarding particle, nuclear process, nuclear stability, particle emission, rate of nuclear decay, spontaneous nuclear reaction		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS1-8: • Rocks from the Tuna Creek area of the Grand Canyon were tested and found to contain less lead (Pb) and more uranium (U) than rocks from the Elves Chasm area of the Grand Canyon. • A brand new nuclear fuel rod containing 3% U-235 was used in a nuclear reactor in New Jersey for 18 months. When it was taken out the reactor, it was found to contain 0.8% U-235, 5.2% fission products, and 1.2% plutonium. • Scientists in Dubna, Russia, after using a heavy ion accelerator to smash berkelium and detected atoms of elements 115 and 113 along with alpha particles.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
1. Select or identify from a collection of components, including distractors, the components needed to model the changes in nuclear composition and energy released during fission, fusion, and/or radioactive decay.			
2. Identify missing components, relationships, or other limitations of the model.			

3. Describe, select, or identify the relationships among components of the nucleus and/or nuclear processes that explains the release or absorption of energy and/or the conservation of protons and neutrons.
4. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing a release or absorption of energy from a nuclear process. This does not include labeling an existing diagram.
5. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.</td><td>PS2.A: Forces and Motion
• Newton’s second law accurately predicts changes in the motion of macroscopic objects.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.
• Stating the law or naming the law is not part of this PE.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Velocity, acceleration, net force, friction, air resistance, impulse, vectors, slope, y-intercept</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Jerk, terminal velocity</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">The phenomenon for these PEs are the given data. Phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc).

Some example phenomena for HS-PS2-1:
• Force is removed from two vehicles’ accelerator pedals. The vehicles’ positions over time are given.
• A water tank railcar is pulled by a train engine at constant speed and develops a leak allowing water to escape. The position and velocities of the water tank and train over time are given.
• A heavy model rocket rises a shorter distance than a lighter model rocket using the same type of engine. The position of each rocket over time is given.
• A falling skydiver’s velocity increases for several minutes and then reaches a maximum speed. The velocity of the skydiver over time is given.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Organize and/or arrange (e.g., using illustrations and/or labels), make calculations, or summarize data to highlight trends, patterns, or correlations.
2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends or relationships in the motion of a macroscopic object. This may include sorting out distractors.
3. Construct, state, or select a claim or propose a design solution based on the relationships identified in the data.
4. Use relationships identified in the data to predict the motion of and changes in the motion of macroscopic objects.
5. Identify patterns or evidence in the data that supports inferences about the motion of and changes in the motion of macroscopic objects.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena to describe explanations</td><td>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.</td><td>Systems and System Models
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle
• Students should not be deriving formulas but can be using and manipulating them

Content Limits
• Assessment is limited to systems of no more than two macroscopic bodies moving in one dimension.
• <u>Students do not need to know:</u>
o How to use a derivation to show that momentum is conserved only when there is no net force.
o How to derive formulas regarding conservation of momentum.
o How to resolve vectors and apply the understanding that momentum must be conserved in all directions.
o Newton’s Laws by name</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Friction, transfer, deceleration, frame of reference, net force, acceleration, velocity, internal, external, conversion, closed system, Newton’s Second Law, collision, vector</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Elastic collision, inelastic collision, inertial frame of reference</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-2:
• A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball, causing the 8-ball to move. The 8-ball slows down until it comes to a rest 5 seconds after the collision.
• Two pool balls collide with each other and two soccer balls collide with each other. After the collision, the soccer balls come to a stop quicker than the pool balls.
• A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball. The velocity of the 8-ball 1 second after the collision is greater than the velocity of the 8-ball 2 seconds after the collision.</td></tr>
</table>

	• Two hockey pucks collide during an ice hockey practice. A player realizes that the two pucks take a long time to come to rest on the ice. After practice, he makes two street hockey pucks collide on pavement. The pucks come to a stop more quickly than the ones on the ice did.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Make simple calculations using given data to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.	
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.	
3. Calculate or estimate properties or relationships between momentum and other forces based on data from one or more sources.	
4. Identify data or compile from given information, the information needed to support inferences about net force and/or how momentum is conserved within a system. This can include sorting out the relevant data from the given information.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.</td><td>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 (trade-offs) may be needed. (secondary)</td><td>Cause and Effect
• Systems can be designed to cause a desired effect.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment is limited to qualitative evaluations and/or algebraic manipulations</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Exert, acceleration, deceleration, impact, inertia, Newton’s First law, Newton’s Second Law, Newton’s Third Law of Motion, impact, drag, velocity, qualitative, criteria, theoretical model, optimal, deformation, impulse, tradeoff</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Rationale, aesthetics, consideration, representation, aspect, specification, critical, compressibility</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

Some example design problems for HS-PS2-3:</td></tr>
</table>

<table>
<tr><td></td><td>Bikers need to be both protected and have total visibility when riding. Design a helmet that protects the biker from collisions while maintaining awareness for his surroundings.
Phone screens can be easily broken if dropped on the ground. Design a phone case that protects the phone from collisions while maintaining functionality.
Design a material that can be implemented on a pool table, athletic field turf (fake grass), or miniature golf green to prevent wear and tear on the playing surface.
Design an instrument case so that the instrument will still be in good condition even if the case is subject to being dropped or rolled around.</td></tr>
<tr><td colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2">Task Demands</td></tr>
<tr><td colspan="2">1. Identify or assemble from a collection, including distractors, the relevant aspects of the problem, that with the given design solutions, if implemented, will resolve/improve the device by minimizing impact force.</td></tr>
<tr><td colspan="2">2. Using the given information, select or identify the criteria against which the device or solution should be judged.</td></tr>
<tr><td colspan="2">3. Using given data, propose/illustrate/assemble a potential device (prototype) or solution in order to minimize impact forces.</td></tr>
<tr><td colspan="2">4. Using given information, select or identify constraints that the device or solution must meet.</td></tr>
<tr><td colspan="2">5. Using a simulator, test a proposed prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.</td></tr>
</table>

<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>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena to describe explanations.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.

Content Limits
• Assessment is limited to systems with two objects.
• Mathematical models can involve 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.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">attraction, charge, conductor, electric charge, induced electric current, electric field, electromotive force, electromagnetic field, electromagnet, frequency, induction, insulator, magnetic field, magnetic field lines, magnetic force, permanent magnet, polarity, repulsion, resistance, voltage, battery, direction, magnitude, ampere, charged particle, volts, right-hand rule, tesla, vectors,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">electric potential, electromotive force, permeating, quantum property, Laplace force, electrodynamics, magnetic dipole, electrostatic, general relativity, Ampere’s Law, Coulomb force, Lorentz force</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-4:
• A person weighs 150.00 pounds at sea level. At the top of Mount Everest, the same person weighs 149.25 pounds.
• When an uncharged sphere is brought near another stationary uncharged sphere, the stationary uncharged sphere does not move. When a charged sphere is brought near a stationary uncharged sphere, the stationary uncharged sphere always moves towards the charged sphere.
• The constant of proportionality in Coulomb’s Law is 10^{20} times greater than the constant of proportionality in Newton’s Law of Gravitation. However, the force of gravity on objects on Earth is usually much greater than the force exerted by magnets.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

8. Make simple calculations using given data to calculate or estimate the gravitational or electrostatic forces between objects.
9. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate the gravitational or electrostatic forces between objects.
10. Calculate or estimate gravitational or electrostatic properties/relationships based on data from one or more sources.
11. Compile, from given information, the particular data needed for a particular inference about the gravitational or electrostatic forces between objects. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.</td><td>PS2.B: Types of Interactions
• 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)</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>Clarifications and Content Limits</td><td colspan="3">Content Limits
• Assessment is limited to designing and conducting investigations with provided materials and tools.
• Coulomb Law is provided in the stimulus if student is required to make calculations.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">conductor, electric charge, induced electric current, electromotive force, electromagnetic field, electromagnet, induction, insulator, magnetic field, magnetic field lines, permanent magnet, polarity, resistance, voltage, magnitude, ampere, charged particle, volts, right-hand rule, tesla, vectors,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">electric potential, electromotive force, permeating, quantum property, Laplace force, electrodynamics, magnetic dipole, electrostatic, general relativity, Ampere’s Law, Coulomb force, Lorentz force</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-5:
• Paperclips on a table are picked up by a wire when both ends of the wire are attached to a battery.
• When an electric current flows through a coil near a strong magnet, the coil rotates.
• The light bulb in a closed circuit turns on when a magnet moves near the wire in the circuit.
• A wind turbine built with a neodymium magnet produces more electricity than a wind turbine built with a ferrite magnet.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify from a list, including distractors, the materials/tools/steps needed for an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.</td></tr>
</table>

2. Identify the outcome data that should be collected in an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.
3. Evaluate the sufficiency and limitations of data collected to explain the phenomenon.
4. Make and/or record observations about the magnetic field created by an electric current or the electric current created by a changing magnetic field.
5. Analyze, manipulate, interpret and/or communicate the data from an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.
6. Explain or describe the causal processes that lead to the observed data.
7. Select, describe, or illustrate a prediction made by applying the findings from an investigation about electric currents and magnetic fields.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS2-6
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Communicate scientific 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).</td><td>PS1.A: Structure and Properties of Matter
• The structure and properties of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary)

PS2.B: Types of Interactions
• Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, ad transformations of matter, as well as the contact forces between material objects.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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 is limited to provided molecular structures of specific designed materials.

Content Limits
• <u>Students do not need to know:</u> specific molecular structures; specific names of synthetic materials such as vinyl, nylon, etc.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Macroscopic, microscopic, electrical conductivity, long chained molecules, contact force, electron sharing, electron transfer, polymers, network material, surface tension, synthetic polymer, monomer, reactivity, intermolecular forces, charge, conductor, electric charge, insulator, permanent magnet, polarity, resistance, charged particle, ionic bond, covalent bond, hydrogen bond, ductile, malleable, friction</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">electric potential, electromotive force, permeating, quantum property, Laplace force, electrodynamics, magnetic dipole, electrostatic, general relativity, Ampere’s Law, Coulomb force, Lorentz force, Van der Waals forces, organic molecules</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-6:
• Zinc oxide was dissolved in water and the resulting solution was very difficult to stir. Upon the addition of a clear, amber colored liquid, the solution became much thinner and easier to stir.
• Water was spilled on two shirts. One shirt absorbed the water very quickly, leaving a large wet spot. On the other shirt, the water formed tiny spheres and bounced off, leaving the shirt dry.</td></tr>
</table>

	• A sample of cotton fabric was dyed with two different kinds of dye and then was washed several times to determine how well the dye stayed in the fabric. One dye faded over time, the other did not. • Food cooked in a bronze-colored pot cooked quickly and evenly. Food cooked in a silver-colored pot took longer and was not evenly cooked.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence that electrostatic forces on the atomic and molecular scale result in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.*
2. Identify relationships or patterns in scientific evidence to describe how electrostatic forces are related to properties of designed materials.
3. Identify and communicate evidence for how the structure and properties of matter and the types of interactions of matter at the atomic scale determine its function.
4. Synthesize an explanation for the function and properties of designed materials that incorporates the scientific evidence from multiple sources.*
5. Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-1
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 energy flows in and out of the system are known.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create a computational model or simulation of a phenomenon, designed device, process or 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.

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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on explaining the meaning of mathematical expressions used in the model.

Content Limits
• Assessment is limited to:
    o Basic algebraic expressions or computations
    o Systems of two or three components
    o Thermal energy, kinetic energy, and/or the energies in gravitational, magnetic and electric fields.
• <u>Students do not need to know:</u> detailed understanding of circuits or thermodynamics</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Mechanical energy, potential energy, conversion, kinetic energy, conduction, electrical circuit, electrical current, heat radiation, insulate, resistor, Volt, Amp, Ohm's Law</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Entropy, second law of thermodynamics, thermodynamics, Stirling cycle, Carnot cycle, capacitor, inductance, inductor, Faradays law</td></tr>
</table>

Phenomena	
Context/ Phenomena	Some example phenomena for HS-PS3-1: • A block is attached to a spring and laid down on a table. The spring is stretched by pulling the block a certain distance. The spring is then released. As the block oscillates back and forth, the amplitude of each successive oscillation gets smaller until the block stops moving. • A light bulb is hooked up to an energy source. When a resistor is added in series to the circuit, the brightness of the light bulb dims. • Two metal pots are placed on a stove top. Pot 1 has a metal handle while Pot 2 has a rubber handle. The stove is turned on and the pots heat up. After 10 minutes, the handle on Pot 1 is much hotter than the handle on Pot 2. • A toy truck is placed at the top of a frictionless ramp. When it travels down the ramp it collides with a stationary toy truck sitting on a horizontal surface (with friction) at the bottom of the ramp. The truck at the bottom of the ramp then begins to move.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
7. Make simple calculations using given data to calculate or estimate the amount of energy in certain components of the system.
8. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate how energy changes in one component of the system affect the energy changes in another component of the system OR how the flow of energy into and out of the system affects the energy change of each component within the system.
9. Calculate or estimate properties for, or the relationships between, each component of the system based on data from one or more sources.
10. Compile, from given information, the particular data needed for a particular inference about how energy changes in one component of the system affects the energy changes in another component of the system. This can include sorting out the relevant data from the given information.

<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>Dimensions</td><td>Developing and Using Models
• 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 movers 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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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
  • The energy stored between two electrically-charged plates.
• Examples of models could include diagrams, drawings, descriptions, and computer simulations

Content Limits
• <u>Students do not need to know:</u>
  o Thermodynamics in detail
  o Gravitational fields
  o Thermonuclear fusion</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Mechanical energy, potential energy, kinetic energy, electric field, magnetic field, molecular energy, heat conduction, circuit, current, heat radiation, work</td></tr>
<tr><td>Science Vocabulary Students are</td><td colspan="3">Entropy, Second Law of Thermodynamics, thermodynamics, root mean velocity, Boltzmann’s constant, gravitational fields, fusion, fission</td></tr>
</table>

Not Expected to Know	
Phenomena	
Context/ Phenomena	Some example phenomena for HS-PS3-2: • Two electrically charged plates, one with a positive charge and one with a negative charge, are placed a certain distance apart. Electron 1 is placed in the middle of the two plates. It accelerates to the positive plate and hits it with a certain velocity. Electron 2 is then placed closer to the negative plate. This electron gains more speed before reaching the positive plate. • A gas is placed inside a container and sealed with a piston. The outside of the container is heated up. The piston begins to move upwards. • A person rubs their hands together. Afterwards their hands feel warm. • A block is attached to a spring and placed on a horizontal table. When the spring is un-stretched, the spring and block do not move. When the spring is stretched to a certain distance (x), the block oscillates back and forth.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include equations used to calculate energy or objects used to set up the experimental model. The model can be a conceptual model (flow chart).	
2. Manipulate the components of a model to demonstrate how energy at the macroscopic scale can be accounted for as a combination of energy associated with the workings of particles at the microscopic scale, result in the observation of the phenomenon.	
3. Make predictions about the effects of changes in the motion or relative position of objects in the model. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.	
4. Identify missing components, relationships, or other limitations of the model showing how energy at the macroscopic scale is affected by the motion and positioning of particles at the microscopic scale.	
5. Describe, select, or identify the relationships among components of a model that describes, or explains, how energy is related to the motion and relative position of objects.	

<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>Dimensions</td><td>Constructing Explanations and Designing Solutions
• 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</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on both qualitative and quantitative evaluations of devices.
• Examples of constraints could include use of renewable energy forms and efficiency.
• Examples of devices could include, but are not limited to:
    • Rube Goldberg devices
    • Wind Turbines
    • Solar cells
    • Solar ovens
    • Generators

Content Limits
• 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>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Electric current, electrical energy, electromagnet, magnetic field, electric field, mechanical energy, renewable energy, generator, wind turbine, Rube Goldberg Device, solar cell, solar oven</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Torque, entropy, molecular energy, second law of thermodynamics, thermodynamics, thermal equilibrium, Stirling engine</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

Some example design problems for HS-PS3-3:
• Use and engine to generate the most light from an LED.</td></tr>
</table>

	• Refine a Stirling Engine to make it run for over 30mins. • Create a solar oven that will cook an egg in 10mins. • Refine a solar cell such that it maximizes energy output.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how the device converts one form of energy into another form of energy. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
3. Using given information, select or identify constraints that the energy converting device or solution must meet.
4. Identify evidence supporting the inference of causation that is expressed in a causal chain.
5. Using given data, propose, illustrate, or assemble a potential energy converting device (prototype) or solution.
6. Using a simulator, test a proposed energy converting prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.

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	**Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**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.
Clarifications and Content Limits	**Clarification Statements** • 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. **Content Limits** • *Assessment is limited to investigations based on materials and tools provided to students.*		
Science Vocabulary Students are Expected to Know	Specific heat, specific heat capacity, kinetic energy, microscopic scale, macroscopic scale, molecular energy, heat conduction, heat radiation, Kelvin, Joules, calorimetry		
Science Vocabulary Students are Not Expected to Know	Entropy, root mean velocity, Boltzmann's constant, gravitational fields, fusion, fission		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS3-4: • The temperature of a can of soda decreases when the can is placed in a container of ice. • Hot coffee cools down after cold cream is added to the cup. • A scoop of ice cream begins to melt when added to cold soda in a glass.		

	• A foam cup has 200 grams of room temperature water after 100 grams of hot water are mixed with 100 grams of cold water.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
6. Identify, make, plan, and/or record observations/outcome data concerning changes in substances' properties in order to provide evidence of transfer of thermal energy within a closed system.
7. Organize, arrange, and/or generate/construct graphs, flowcharts, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations among observations and data concerning transfer of thermal energy within a closed system, and/or the boundaries of a closed system in which thermal energy is transferred.
8. Describe, analyze, and/or summarize data (e.g., using illustrations and/or labels), to identify/highlight trends, perform calculations and other mathematical analyses, and identify patterns or correlations among observations and data concerning the transfer of thermal energy within a closed system.
9. Use evidence to identify the boundaries of a closed system in which thermal energy is transferred.
10. Identify patterns or evidence in the data that support inferences related to the transfer of thermal energy within a closed system.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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

Content Limits
• Assessment is limited to systems containing two objects
• <u>Students do not need to know:</u> Gauss' Law, Ampere's Law, Faraday's Law or anything that requires in depth knowledge of the electromagnetism as a unified force.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Electric current, acceleration, net force, newton's second law of motion, inertia, velocity, magnet, electrical energy, magnetic force, attraction, repulsion, electromagnet, Coulomb's law, electric/magnetic field, potential energy, kinetic energy</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Semiconductor, superconductor, torque, Gauss' Law, Ampere's Law, Lorentz force, Faraday's Law, Lenz's Law</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS3-5:
• Two magnets are held close together such that they attract each other. When the magnets are further away from each other it is easier to keep them apart.
• A light bulb connected to a circuit with a battery lights up. When a stronger battery is placed in the circuit, the light bulb becomes brighter.
• A magnet rotates when placed in a magnetic field perpendicular to the magnet. When the magnet is brought close to the source of the magnetic field, it rotates faster.
• A water molecule is placed in an electric field. After it is released, it begins to rotate. After it rotates 90 degrees, it stops rotating.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon.</td></tr>
<tr><td colspan="4">2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing how the forces between the objects and the energy of each object changes. This <u>does not</u> include labeling an existing diagram.*</td></tr>
</table>

3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.*
4. Make predictions about the effects of changes in orientation of objects, distance between objects or size of magnetic and electric charges on the forces between objects and the energy of each object. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.**
5. Describe, select, or identify the relationships among components of a model that describe or explains the behavior of electric and magnetic fields and/or how that affects the forces between objects and the energy of the objects.
6. Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone development
**TD 4 can only be used with TD2

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-1
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.</td><td>PS4.A: Wave properties
• The wavelength and frequency of a wave are related to each other by the speed of travel of the wave, which depends on the type of wave and the media through which it is passing.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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 Earth.

Content Limits
• Assessment is limited to algebraic relationships and describing those relationships qualitatively.
• Students are not expected to produce equations from memory, like Snell's Law, but the concepts and relationships should be assessed.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Simple wave, vacuum, electromagnetic radiation, radiation, wave source, index of refraction, Snell's Law, angle of incidence, angle of reflection, normal at the point of incidence, critical angle, interface.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Clausius–Mossotti relation, dielectric constant, Fermat's principle, phase velocity, permittivity, permeability.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-1:
• A person uses their car horn in an effort to attract the attention of their friend who is swimming in a pool a short distance away. The friend hears only muffled noises.
• A person opens their curtains so that the sun shines in the window. A diamond in their necklace begins to sparkle brightly.
• An earthquake occurs in Japan. The vibrations are recorded in Brazil, but not in Miami.
• A person sees a fish through the glass wall of a rectangular fish tank. The person moves and looks through the end of the tank. The fish appears to be in a different place.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Make calculations using given data to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.</td></tr>
<tr><td colspan="4">2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.</td></tr>
</table>

3. Calculate or estimate properties or relationships among the frequency, wavelength, and speed of waves in various media based on data from one or more sources.
4. Compile, from given information, the particular data needed for a particular inference about a relationship among the frequency, wavelength, speed of waves, and the media they travel in. This can include sorting out the relevant data from the given information.
5. Use quantitative or abstract reasoning to support a claim/explanation about a particular relationship between the velocity, wavelength, and frequency.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-2
Evaluate questions about the advantages of using a digital transmission and storage of information.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.</td><td>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.</td><td>Stability and Change
• Systems can be designed for greater or lesser stability.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include the specific mechanism of any given device.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Wave pulse, Wi-Fi device, binary, capacity, civilization, interdependence, degradation, emit, pixel, suitability, performance, analog, digital, progress, vacuum, electromagnetic radiation, computer, machine, radio wave, USB, bit, byte, discrete vs. continuous, decode, encode.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Analog jack, HDMI, router, impedance, granularity, bandwidth.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-2:
• A person uses e-mail to back up all of their personal data.
• A person is reading some science papers that were written in 1905 and wonders how people got so much great research done before the internet was invented.
• One day in June 2009 a person noticed that their old analog television stopped broadcasting their favorite television channel.
• A person stays in constant contact with all of their friends and relatives using their cell phone.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify or construct an empirically testable question(s) based on advantages and disadvantages associated with the phenomenon. In addition to other plausible distractors, distractors may include non-testable (“nonscientific”) questions.</td></tr>
<tr><td colspan="4">2. Make and/or record observations about the factors that affect digitally stored or transmitted data.</td></tr>
<tr><td colspan="4">3. Assemble or complete an illustration, flow chart, or graph based on an empirically testable question that is capable of identifying clear advantages or disadvantages associated with digital transmission and storage of information in the phenomenon.</td></tr>
</table>

4. Select or describe conclusions relevant to a question posed and supported by the data, especially inferences about causes and effects.
5. Make predictions about the phenomenon derived from the questions. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors. Predict outcomes when properties are changed, given the inferred cause and effect relationships.
6. Compile, from given information, the particular data needed for a particular inference about the advantages/disadvantages. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the claims, evidence and reasoning behind currently accepted explanations or solutions to determine the merits of arguments</td><td>PS4.A: Wave Properties
• Waves can add or cancel one another as they cross, depending on their relative phase (i.e. relative position of peaks and troughs of 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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Assessment should only test the qualitative aspect of the wave model vs. particle model.
• Examples of a phenomenon could include:
    • Resonance
    • Interference
    • Diffraction
    • Photoelectric Effect

Content Limits
• Assessment does not include using Quantum Theory
• Assessment does not include in depth calculations
• <u>Students do not need to know:</u> Specific types of electromagnetic radiation and their wavelengths/frequencies</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Interference, diffraction, refraction, photoelectric effect, emission, absorption, brightness, resonance, transmission, visible light, transverse wave</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Doppler effect for light (redshift), microwave radiation, ultraviolet radiation, ionize, infrared radiation, wave-particle duality, quantum, quanta, x-ray, gamma rays, radio waves, oscillations, electrostatic induction, Planck’s equation, Planck’s constant, magnetic dipole, electric dipole,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-3:</td></tr>
</table>

	• When light hits a metal, a stream electrons are ejected from the metal. When the color of the light pointed at the metal changes, the kinetic energy of the stream of electrons changes. • Light is made to pass through two small slits on a piece of dark construction paper. The light that goes through the slits is then projected on a second piece of dark of construction. A pattern of bright and dark bands is seen on the second piece of dark construction paper. • The emission spectra of Hydrogen is completely black but for 4 discrete lines violet, blue, green and red color. • A red laser is pointed at a glass prism. The light bends as it goes through the prism. A violet laser is then pointed at the glass prism and the light bends more than the light from the red laser.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data or information, identify the explanation that describes light behaves like a particle and or behaves like a wave.
2. Identify and/or explain the claims, evidence, and reasoning supporting the explanation that light can behave like a particle or a wave, and why certain evidence is best explained by only one of these models.
3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of how light can behave like a particle or a wave.
4. Evaluate the strengths and weaknesses of a claim to explain which pieces of evidence support the fact that light behaves as a particle or a wave.
5. Analyze and/or interpret evidence and its ability to support the explanation that light can behave as both a wave and a particle.
6. Provide and/or evaluate reasoning to support the explanation that light can behave as both a wave and a particle and that some evidence is only supported by one of the models.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.</td><td>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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment is limited to qualitative descriptions.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Interference, diffraction, refraction, photoelectric effect, emission, absorption, brightness, resonance, photon, visible light, transverse wave, phase, transparent, light scattering, light transmission, radio wave, visible light, electric potential, gamma ray, infrared radiation, ionize, microwave, ohm, photoelectric, ultraviolet,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Doppler effect for light (redshift), microwave radiation, ultraviolet radiation, infrared radiation, wave-particle duality, quantum, quanta, x-ray, gamma rays, oscillations, electrostatic induction, Planck’s equation, Planck’s constant, magnetic dipole, electric dipole</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-4:
• A student places a glass bowl filled with soup in a microwave. After a minute in the microwave, the soup is hotter than the glass bowl.
• A lit candle is placed at one end of a tube filled with carbon dioxide. A student standing at the other end of the tube can see the candle’s flame. When looking through a monitor that looks at the infrared radiation emitted by the flame, the student can no longer see the candle’s flame.
• Astronauts aboard the International Space Station are exposed to a different amount of ultraviolet radiation from the sun than humans on Earth.
• In 2020, NASA is sending a rover to Mars with multiple materials on it in order to test whether or not they can be used as space suits for future Mars travelers. Orthofabric was chosen to be sent on the mission, while Spectra was not.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Analyze and/or interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.*
2. Identify relationships or patterns in scientific evidence to describe how different frequencies of electromagnetic radiation effect matter when absorbed.
3. Illustrate, graph, or identify relevant features or data that can be used to communicate information about the effect that different frequencies of electromagnetic radiation have on matter when it is absorbed.
4. Synthesize an explanation for the effects of electromagnetic radiation on matter when absorbed that incorporates the scientific evidence from multiple sources.*
5. Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.
6. Identify the cause and effect reasoning in a claim from the sources, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g. extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism).

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-5
Communicate technical information how some technological devices use the principles of wave behavior and wave interaction with matter to transmit and capture information and energy.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• 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).</td><td>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 digitalized (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
• 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.</td><td>Cause and Effect
• Systems can be designed to cause a desired effect.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology.

Content Limits
• Assessments are limited to qualitative information.
• Assessment does not include band theory.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">refraction, reflection, infrared, electromagnetic spectrum, constructive wave, destructive wave, restoring, periodic motion, mechanical wave, interference, velocity, diffraction, standing wave, nodes, angle of incidence, rarefaction, superposition, medium, longitudinal wave, transverse wave, standing wave, ultrasound, dispersion, intensity, prism, resonance, radar, sonar, virtual image, real image</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Constructive interference, destructive interference, light ray, total internal reflection</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering Standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.</td></tr>
</table>

	Some example design problems and/or solutions for HS-PS4-5: • When using light detection and ranging (LiDAR) over a forested area the light reflects off multiple surfaces and affects the accuracy of elevation models. • Solar cells only capture about 20% of the energy from the sun. • Marine radar is mounted to the front of ships used for collision avoidance. Occasionally the radar can distort the coast line and report a straight coastline when it is curved. • Water reflects radar, blanking out entire regions of radar screens.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence of how devices use wave behavior, the absorption of photons, and the production of electrons to solve problems.
2. Identify relationships or patterns in scientific evidence to describe how waves are used to produce, transmit, and capture signals in electronic devices.
3. Illustrate, graph, or identify relevant features or data that can be used to communicate wave information and
4. Synthesize an explanation for the function and properties of designed materials that incorporates the scientific evidence from multiple sources.
5. Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.

<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>Dimensions</td><td>Constructing Explanations and Designing Solutions
• 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.</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 the connections of these components in order to solve problems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• 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>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Nucleus, chromosome, DNA, nucleated cell, transcription, double helix, adenine, guanine, cytosine, thymine, deoxyribose, phosphate, hydrogen bond, nucleotide base, mRNA, amino acid, translation</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">primary, secondary, tertiary protein structure, tRNA, ribosome.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Sample phenomena for HS-LS1-1:
• Sweat glands cool the body by releasing sweat onto the skin’s surface. A protein transports salt to help carry the water to the skin’s surface. In some individuals, the salt is not reabsorbed and is left on the skin.
• When a blood vessel is cut, several proteins act to form a blood clot. This blood clot helps to stop the loss of blood from the body. In some individuals, when a blood vessel is cut, a blood clot does not form.
• During cell division, a copy of DNA in the cell is made. Sometimes mistakes are made in the DNA copy that are corrected by specific proteins. In some cells, when those mistakes in the DNA are not corrected, uncontrolled cellular division results.
• After a person eats, sugars from food are absorbed from the bloodstream into the body’s cells. Insulin—a polypeptide hormone—allows those cells to absorb glucose from the bloodstream. In some individuals, sugars are not absorbed into the body’s cells and are left in the bloodstream.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

9. Describe the cause and effect relationship between a DNA sequence and the structure/function of a protein. This may include indicating the directions of causality in a model or completing a cause and effect chain.
10. Describe, identify, or select evidence that supports or contradicts a claim about the role of DNA in causing the phenomenon. The evidence may be obtained from valid source(s) or might be generated by students using a simulation.
11. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes to a DNA sequence in protein structure and function. Predictions may be selected from a collection of possibilities, including distractors, or they might be illustrated or described in writing.
12. Use evidence to construct an explanation of how protein structure and subsequent function depend on a DNA sequence.
13. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-2
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include interactions and functions at the molecular or chemical reaction level (e.g., hydrolysis, oxidation, reduction, etc.).
• Assessment does not include mutations in genes that could contribute to modified bodily functions.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Circulatory, respiratory, digestive, excretory, nervous, immune, integumentary, skeletal, muscle, reproductive, external stimuli, cell, tissue, organ,</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Synaptic transmission, neuron, neurotransmitter, biofeedback, hormonal signaling.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-2:
• After a healthy person eats a large meal, both their blood pressure and heart rate increase.
• When a normal adult male exercises, both his breathing rate and heart rate increase.
• The area around a person’s skin where a small scab has formed feels warm to the touch.
• Skin surface capillaries dilate when a person feels hot.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete an illustration or flow chart that is capable of representing how structures in two (or more) body systems interact to carry out normal, necessary bodily functions. This <u>does not</u> include labeling an existing diagram.*</td></tr>
</table>

2. Using the developed model, identify and describe the relationships between the structures and their coordinated functions in two (or more) body systems.
3. Using the developed model, show that interacting systems have a hierarchical organization and provide specific functions within the body at those specific levels or organization.*
4. Make predictions about, or generate explanations for, how additions/substitutions/removal of certain components in the model can interrupt or change the relationships between those components and, thus, the bodily functions carried out by those structures in two (or more) body systems.
5. Given models or diagrams of hierarchical organization of interacting systems, identify the components and the mechanism in each level of the hierarchy OR identify the properties of the components that allow those functions to occur.
6. Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<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>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence. 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>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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.

Content Limits
• Assessment does not include the cellular processes involved in the feedback mechanism.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Equilibrium, steady state, stable state, balanced state, stimulus, receptor, biotic factor, abiotic factor, external environment, internal environment, muscle, nerve, hormone, enzyme, chemical regulator, gland, system, metabolism, disturbance, fluctuation, maintenance, concentration, hibernation, convection, conduction, radiation, evaporation.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Effector, osmoregulation, conformer, set point, sensor, circadian rhythm, acclimatization, thermoregulation, endothermic, ectothermic, integumentary system, countercurrent exchange, bioenergetics, basal metabolic rate, standard metabolic rate, torpor, poikilotherm, homeotherm, countercurrent heat exchange.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-3:
• Fruit ripeness (positive feedback loop):
    ○ In nature, a tree or bush will suddenly ripen all of its fruits or vegetables without any visible signal.
• Human blood sugar concentration (negative feedback loop):
    ○ The liver both stores and produces sugar in response to blood glucose concentration.
    ○ The pancreas releases either glucagon or insulin in response to blood glucose concentration.
• Sunning lizards (negative feedback loop):
    ○ Lizards sun on a warm rock to regulate body temperature.
• Thermoregulation in dolphins due to counter-current arrangement of veins around arteries (negative feedback loop):
    ○ The counter-current system minimizes the loss of heat incurred when blood travels to the different parts of dolphins’ bodies.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify the outcome data that should be collected in an investigation to provide evidence that feedback mechanisms maintain homeostasis. This could include measurements and/or identifications of changes in the external environment, the response of the living system, stabilization/destabilization of the system's internal conditions, and/or the number of systems for which data are collected.
2. Make and/or record observations about the external factors affecting systems interacting to maintain homeostasis, responses of living systems to external conditions, and/or stabilization/destabilization of the systems' internal conditions.*
3. Identify or describe the relationships, interactions, and/or processes that contribute to and/or participate in the feedback mechanisms maintaining homeostasis that lead to the observed data.
4. Using the collected data, express or complete a causal chain explaining how the components of (a) mechanism(s) interact in response to a disturbance in equilibrium in order to maintain homeostasis. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
5. Evaluate the sufficiency and limitations of data collected to explain the cause and effect mechanism(s) maintaining homeostasis.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-4
Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>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.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.

Content Limits
• <u>Students do not need to know</u>: Specific names of the stages of mitosis – Interphase, G1 phase, S phase, G2 phase, prophase, metaphase, anaphase, telophase, cytokinesis.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Nucleus, chromosome, sister chromatids, sperm cell, egg cell, fertilize, genome, gene, differential gene expression, cellular differentiation, cellular division, cytoplasm, daughter cell, parent cell, somatic cell, cell cycle, homologous, haploid, diploid, DNA.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Spindle, metaphase plate, cleavage furrow, chromatin modification, transcription regulation initiation, enhancers, transcription factors, post-transcriptional regulation; noncoding RNAs, cytoplasmic determinants, inductive signals, chiasmata, kinetochore, microtubule.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-4:
• Genomic sequencing of a parent cell and one of its daughter cells reveals that both have the same genetic makeup.
• At the end of an hour, approximately 30,000 skin cells were shed by a person, but a loss of mass was not noticeable.
• Ears and noses can be grown from stem cells in laboratory.
• Plant cells in a root tip longitudinal cross section are different sizes and shapes.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete an illustration or flow chart that is capable of representing how a parent (somatic) cell is formed through fertilization, undergoes cellular division, forming daughter cells, and how those daughter cells</td></tr>
</table>

	contain all genetic material from the parent cells but differentiate via gene expression necessary. This does **not** include labeling an existing diagram.*
2.	Using the model, identify and describe the relationship between the amount and composition of the genetic material that daughter cells receive from parent cells.
3.	Using the model, show that in multicellular organisms, different cell types arise from differential gene expression, not because of dissimilar genetic material within the cell's nucleus.
4.	Use a model of cellular division and differentiation to explain/illustrates the relationships between components that allow multicellular organisms to grow and carry out specific and necessary functions.*
5.	Given models or diagrams of cellular division and differentiation, show that cells form tissues and organs that have specific structures and interact to carry out specific and necessary functions.
6.	Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-5
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model based on evidence to illustrate the relationship between systems or between components of a system.</td><td>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.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include specific biochemical steps or cell signaling pathways.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Organic, hydrocarbon, net transfer, chloroplast, chlorophyll, cytoplasm, mitochondria, vacuole, nucleus, protein, ATP, amino acid, autotroph(s), heterotroph(s), algae</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Thylakoid, NADP(H/$^+$), Calvin cycle, carbon fixation, redox reactions, electron transport chain, oxidative phosphorylation, photoautotroph(s), mesophyll, stomata, stroma, thylakoids, thylakoid membrane, light reactions, carotenoids, cytochrome complex, C_3 pants, C_4 plants</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-5:
• A maple tree in Washington state survives in the winter after losing all of its leaves.
• The waters of the Laguna Grande lagoon in Puerto Rico give off a bluish-green glow at night when disturbed.
• On the sill of a stained glass window, a soy plant behind the red glass panel grew taller than a soy plant behind the green glass panel.
• In a parking lot in the city of Bordeaux, France a tank filled with algae produces a green light.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete, from a collection of potential model components and distractors, an illustration or flow chart that is capable of representing the transformation of light energy into stored chemical energy.</td></tr>
<tr><td colspan="4">2. Use a model to identify and describe the relationships in terms of matter and/or energy between the reactants and the products of photosynthesis.*</td></tr>
</table>

3. Use a model to show the transfer of matter and flow of energy between an organism and its environment during photosynthesis.*
4. Make predictions about how additions/substitutions/removals of model components affect the transformation of light energy into stored chemical energy.*
5. Sort relevant from irrelevant information to support a model that demonstrates how sugar and oxygen are produced by carbon dioxide and water through the process of photosynthesis.
6. Given models or diagrams of photosynthesis, identify the components and the mechanism in each scenario OR identify the properties of the components that allow photosynthesis to occur.*
7. Identify missing components, relationships, or other limitations of a model intended to show how photosynthesis transforms light energy into stored chemical energy.
8. Describe changes of energy and matter that occur in a system due to photosynthesis.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• Sugar molecules 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.</td><td>Energy and Matter
• Changes of energy and matter in a system can be described as energy and matter flowing into, out of, and within that system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using evidence from models and simulations to support explanations.

Content Limits
• Assessment does not include the details of the specific chemical reactions or identification of macromolecules.
• <u>Students do not need to know:</u> Specific biochemical pathways and processes. Specific enzymes, oxidation-reduction</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Hydrocarbon, carbohydrate, amino acid, nucleic acid, DNA, ATP, lipid, fatty acid, ingestion, rearrangement, stable, open system.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Endothermic reaction, exothermic reaction, aerobic respiration, oxidation, reduction, oxidation-reduction reaction, glycolysis, citric acid cycle, electron transport chain.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-6:
• Hagfish produce and are covered in a thick layer of protective slime.
• The black widow spider's silk is several times as strong as any other known spider silk, making it about as durable as Kevlar.
• The female silk moth, releases a pheromone that is sensed by the male's feather-like antennae, inducing his excited fluttering behavior.
• The bombardier beetle release a boiling, noxious, pungent spray that can repel potential predators.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Describe, identify, or select evidence supporting or contradicting a claim that sugar molecules containing organic elements (e.g., carbon, hydrogen, and oxygen) that are ingested by an organism are broken down and rearranged via chemical reactions to form proteins, lipids, and nucleic acids.	
2. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.	
3. Express or complete a description of the flow of energy and/or matter within and between living systems. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*	
4. Articulate, describe, or select the relationships, interactions, reactions and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products.*	
5. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in the amount and types of organic molecules ingested and the amount and type of products formed within a living system.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>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.</td><td>Energy and Matter

• Energy cannot be created or destroyed—it only moves between one place and another, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.

Content Limits
• Students aren’t expected to identify the steps or specific processes involved in cellular respiration.
• Assessment does not include mechanisms of cellular respiration (enzymatic activity, oxidation, molecular gradients, etc.).
• <u>Students do not need to know:</u> enzymes, ATP synthase, metabolism, biochemical pathways, redox reactions, molecular transport.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">ATP, chemical bonds, energy transfer, glycolysis, enzymes, mitochondria, cytosol, cytoplasm, nitrogen, adenine, phosphate, amino acid.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biochemical, fatty acids, oxidizing agent, electron acceptor, biosynthesis, locomotion, phosphorylation, electron transport chain, chemiosmosis, pyruvate, pentose.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-7:
• A young plant is grown in a bowl of sugar water. As it grows, the amount of sugar in the water decreases.</td></tr>
</table>

	• A bacterial colony in a petri dish is continually provided with sugar water. Over the course of a few days, the bacteria grow larger. When sugar water is no longer provided, the colonies shrink and some disappear. • A person feels tired and weak before eating lunch. After eating some fruit, the person feel more energetic and awake. • An athlete completing difficult training feels that her muscles recover and repair faster when she eats more food in a day, compared to when she ate less food in a day.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
14. Assemble or complete an illustration or flow chart that is capable of representing the transformation of food plus oxygen into energy and/or new compounds. This *does not* include labeling an existing diagram.
15. Using the developed model, identify and describe the relationships between the reactants of the transformation and the products of the transformation.*
16. Using the developed model, show that matter and energy are only rearranged during cellular respiration, but never created or destroyed.
17. Make predictions about how additions/substitutions/removals of certain components can maintain/destroy the balance of the food plus oxygen → energy/new compounds reaction.*
18. Given models or diagrams of cellular respiration, identify the components and the mechanism in each scenario OR identify the properties of the components that allow cellular respiration to occur.
19. Identify missing components, relationships, or other limitations of the model.
20. Describe, select, or identify the relationships among components of a model that describe or explain cellular respiration.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-1
Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical and/or computational representations of phenomena or design solutions to support explanations</td><td>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 challenges such as predation, competition and disease. Organisms would have the capacity to produce populations of greater 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.</td><td>Scale, Proportion, and Quantity
• The significance of a phenomenon is dependent on the scale, proportion, and quantity involved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.
• Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data.

Content Limits
• Assessment does not include deriving mathematical equations to make comparisons.
• <u>Students do not need to know:</u> Calculus/advanced mathematics (e.g., exponential growth and decay).</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Predation, interdependent, disturbance, equilibrium of ecosystems, fluctuation, stable, biotic, abiotic, sustain, anthropogenic, overexploitation, urbanization, population, emigrants, immigrants, exponential, generation, rebounding, limiting resources, logistic, competition, negative feedback, population control.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Dispersion, demography, survivorship curve (J or S), reproductive table, semelparity, iteroparity, metapopulation, demographic transition, resource partitioning, Shannon diversity, biomanipulation, density dependent selection (K-selection), density independent selection (r selection), intrinsic factors.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-1:
• On Ngorogoro Crater in Tanzania in 1963, a scientist sees that there are much fewer lions than there were on previous visits.
• On St. Matthew Island, reindeer were introduced in 1944, but today no reindeer can be found on the island.
• In Washington State, more harbor seals are present today than in the past.</td></tr>
</table>

	• In Alaska, you can see many more brown bears in Lake Clark National Park than in Denali National Park.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Make calculations using given data to calculate or estimate factors affecting the carrying capacity of an ecosystem.*
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting the carrying capacity of ecosystems of different scales.*
3. Calculate or estimate properties of or relationships between factors affecting the carrying capacity of an ecosystem based on data from one or more sources.
4. Compile, from given information, the data needed for a particular inference about factors affecting the carrying capacity of an ecosystem. This can include sorting out the relevant data from the given information and representing the data through graphs, charts, and/or histograms.
5. Use quantitative or abstract reasoning to make a claim about the factors that affect the carrying capacity of an ecosystem.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical representations of phenomena or design solutions to support and revise explanations.</td><td>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 results from factors such 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 greater 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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data.

Content Limits
• Assessment is limited to provided data.
• <u>Students do not need to know</u>: Calculus/advanced mathematics (e.g., exponential growth and decay)</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Carrying capacity, anthropogenic changes, overexploitation, extinction, demographic, population pyramid, deforestation, habitat fragmentation, sustainable, abiotic factor, biotic factor, species richness, symbiosis, niche, fragile ecosystem, biodiversity index, zero population growth, density, dispersion, immigration, emigration, limiting factor</td></tr>
<tr><td>Science Vocabulary</td><td colspan="3">Water regime, direct driver, eutrophication, species evenness, range of tolerance, realized niche, niche generalist, niche specialist, edge habitat, endemic species, logistic growth model, exponential</td></tr>
</table>

Students Are Not Expected to Know	population growth, mark-recapture method, territoriality, demography, cohort, survivorship curve, reproductive table, life history, semelparity, iteroparity, K-selection, r-selection, dieback.
Phenomena	
Context/ Phenomena	Some example phenomena for HS-LS2-2: • After brown tree snakes were accidentally introduced to Guam in the 1950s, 11 native bird species went extinct. • When European settlers decreased the wolf population for safety, deer populations thrived and overconsumed native plant species. • California's Central Valley can support fewer waterfowl in the winter during drought. • The cones of Lodgepole pines do not release their seeds until a fire melts the resin that keeps them sealed.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Make simple calculations using given data to calculate or estimate factors affecting biodiversity and populations in ecosystems.	
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting biodiversity and populations in ecosystems of different scales.	
3. Calculate or estimate properties of or relationships between factors affecting biodiversity and populations in ecosystems based on data from one or more sources.	
4. Compile, from given information, the data needed for a particular inference about factors affecting biodiversity and populations in ecosystems. This can include sorting out the relevant data from given information.	
5. Construct an explanation regarding the relationship between biodiversity and populations in ecosystems of different scales using the given, calculated, or compiled information.	
6. Revise or evaluate a given explanation of the relationship between biodiversity and populations in ecosystems of different scales based on the given, calculated, or compiled information.	

<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>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, 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>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for the processes.</td><td>Energy and Matter
• Energy drives the cycling of matter within and between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.
• Emphasis is on conceptual understanding that the supply of energy and matter restricts a system’s operation; for example, without inputs of energy (sunlight) and matter (carbon dioxide and water), a plant cannot grow.

Content Limits
• Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.
• Students do not need to know: lactic acid vs. alcoholic fermentation, chemical equations for photosynthesis, cellular respiration, or fermentation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Organic compound synthesis, net transfer, biomass, carbon cycle, solar energy</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Lactic acid fermentation, alcoholic fermentation, glycolysis, Kreb’s cycle, electron transport chain.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-3:
• After running for a long period of time, human muscles develop soreness and a burning sensation, and breathing rate increases.
• Bread baked with yeast looks and tastes differently than bread that is baked without yeast.
• A plant that is watered too much will have soft, brown patches on their leaves and will fail to grow.
• Cyanobacteria differ from other bacteria in that cyanobacteria appear blue-green in color and also lack flagella.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Describe, identify, or select evidence supporting or contradicting a claim about the role of photosynthesis and aerobic and anaerobic respiration in the cycling of matter and energy in an ecosystem.
2. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.
3. Express or complete a description of the flow of energy and/or matter between organisms. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.*
4. Articulate, describe, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products.*
5. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the flow of matter and energy between organisms.

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	**Using Mathematical and Computational Thinking** • Use mathematical representations of phenomena, or design solutions to support claims.	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** ▪ Plants or algae from 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.
Clarifications and Content Limits	**Clarification Statements** • 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. **Content Limits** • Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy. • Students do not need to know: the specific biochemical mechanisms or thermodynamics of cellular respiration to produce ATP or of photosynthesis to convert sunlight energy into glucose.		
Science Vocabulary Students Are Expected to Know	Interdependent, nutrient, hydrocarbon, transfer system, equilibrium of ecosystems, decomposer, producer, ATP, solar energy, predator-prey relationship, trophic level		
Science Vocabulary Students Are Not Expected to Know	Detritivore, denitrification, thermodynamics, nitrogen fixation, biogeochemical cycle, anaerobic process.		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-LS2-4: • In the 6,000-hectare rainforest of San Lorenzo, Panama, there are 312 arthropods for every mammal, including humans.		

	• In Silver Springs, Florida, the biomass of plants is 809 g/m^2, while the biomass of large fish is 5 g/m^2. • A herd of grazing caribou in the Seward Peninsula of Alaska are seen eating the leaves of birch trees in July. In December, they are seen eating tree lichen. • A pine tree growing in a forest remains in one location throughout its lifetime. A fox in the same forest moves around every day of its life.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Calculate or estimate changes or differences in matter and energy between trophic levels of an ecosystem. **
2. Illustrate, graph, or identify a mathematical model describing changes in stored energy through trophic levels of an ecosystem.**
3. Compile and interpret data from given information to establish the relationship between organisms at different trophic levels.*
4. Use quantitative or abstract reasoning to make a claim about the cycling of matter and flow of energy through the trophic levels of an ecosystem. This may include sorting relevant from irrelevant information.*
5. Identify and describe the components of a mathematical representation of an ecosystem that could include relative quantities related to organisms, matter, energy, and the food web of that ecosystem.

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TDs 1 and 2 may be used for stand-alones in combination with TD3 and TD4.

<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>Dimensions</td><td>Developing and Using Models
• 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, or 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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of models could include simulations and mathematical models.

Content Limits
• Assessment does not include the specific chemical steps of photosynthesis and respiration.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Recycle, consumer, transform, organism, convert, decomposer, producer, hydrocarbon, microbes, ATP</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Endothermic reaction, exothermic reaction, free energy, hydrolysis, oxidation.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-5:
• A herd of cows grazing in a field wear balloon-like backpack devices on their backs.
• A piece of coal preserving a fossil leaf imprint is burned within the furnace of a coal-fired electrical power plant. Smoke generated from the fire escapes out of a smoke stack
• Several acres of trees are cut down and burned, generating clouds of smoke.
• Two mice die in the woods in November, one in Massachusetts and one in Florida. The Florida mouse decomposes much more quickly than the Massachusetts mouse.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete an illustration or flow chart that is capable of representing how the processes of photosynthesis and cellular respiration cycle carbon by various chemical, physical, geological, and biological</td></tr>
</table>

	processes through two or more spheres (biosphere, atmosphere, hydrosphere, geosphere). This *does not* include labeling an existing diagram.
2.	Using the developed model, identify and describe the relationships between the processes of photosynthesis and cellular respiration, and the coordinated functions of transferring carbon among two or more spheres (biosphere, atmosphere, hydrosphere, geosphere).
3.	Using the developed model, show that photosynthesis and cellular respiration are important parts of the overall carbon cycle that transfers carbon through two or more spheres (biosphere, atmosphere, hydrosphere, geosphere).
4.	Make predictions about, or generate explanations for, how substitutions of certain components in the model can interrupt or change the relationships between, or functions of, those components, thus effecting the cycling of carbon through the various spheres (biosphere, atmosphere, hydrosphere, geosphere).
5.	Given models or diagrams* of the processes of photosynthesis and cellular respiration, identify the components and the mechanisms in each process that cycle carbon OR identify the properties of the components that allow those functions to occur.
6.	Identify missing components, relationships, or other limitations of the model.
7.	Modify/augment/add to the model to change or add steps that can alter the cycling of carbon through the various spheres (biosphere, atmosphere, hydrosphere, and/or geosphere).

*Labeled diagrams by themselves are not usually sufficient to serve as models.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-6
Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence

• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</td><td>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.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.
• To show full comprehension of the PE, the student must demonstrate an understanding that, in a stable ecosystem, the average activity by the nutrients, decomposers, producers, primary consumers, secondary consumers, and tertiary consumers remains relatively consistent. When each of these levels has high levels of diversity, the ecosystem is stable because the group as a whole is better able to respond to pressures. However, even a healthy, diverse ecosystem is subject to extreme changes when faced with enough pressure.

Content Limits
• Assessment does not include Hardy-Weinberg equilibrium calculations.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Biosphere, biodiversity, carbon cycle, water cycle, nitrogen cycle, fluctuation, consistent, stable, equilibrium, species, emergence, extinction, niche, native, non-native, invasive, overgrazing, human impact, succession, primary succession, secondary succession.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Genetic drift, founder effect, Hardy-Weinberg, intermediate disturbance hypothesis, species-area curve.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-6:
• The populations of rabbits and deer in the Florida Everglades significantly decreased with the introduction of the Burmese python.
• Biodiversity of an area of the Amazon rainforest is affected differently in sustainable and non-sustainable lumber farms.</td></tr>
</table>

	• After a fire, the biodiversity of a forest immediately decreases but eventually increases. • An increase in mouse populations are observed the year after a flood but return to pre-flood numbers the following year.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data or information, identify the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
2. Identify and/or explain the claims, evidence, and reasoning supporting the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the complex interactions in ecosystems, factors that affect biodiversity, relationships between species and the environment, and changes in numbers of species and organisms in a stable or changing ecosystem.
4. Evaluate the strengths and weaknesses of a claim to explain the relationship of biodiversity and the environment in an ecosystem based on the evidence or data provided.*
5. Analyze and/or interpret evidence and its ability to support the explanation of the resiliency of an ecosystem in response to different levels of change.*
6. Provide and/or evaluate reasoning to support the explanation that an ecosystem remains relatively consistent when faced with modest disturbances, but it may experience extreme changes or fluctuations in biodiversity when faced with extreme disturbances.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-7
Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.</td><td>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)

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
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of human activities can include urbanization, building dams, and dissemination of invasive species.

Content Limits
• Assessment does not include physical equations describing mechanics of solutions or mechanics of engineered structures.
• <u>Students do not need to know</u>: quantitative statistical analysis, specific conditions required for failure, specifics of constructing the solution.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Carrying capacity, competition, urbanization, conversation biology, endangered species, threatened species, introduced species, overharvesting, extinction, greenhouse effect, carbon footprint</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Laws of thermodynamics, Hardy-Weinberg equilibrium, Lotka-Volterra equations, allelopathy, density-dependent population regulation, extinction vortex, minimum viable population (MVP), effective population size, movement corridor, biodiversity hot spot, zoned reserve, critical load, biological magnification, assisted migration, sustainable development.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example of phenomena for HS-LS2-7:
• The spread of cities through urbanization has destroyed wildlife habitats across the planet.
• Air pollution from driving cars has made the air unsafe to breathe in many areas.
• Dams have led to flooding of large areas of land, destroying animal habitats.</td></tr>
</table>

	• Fishing has drastically changed marine ecosystems, removing certain predators or certain prey.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how human activity impacts the environment. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Use an explanation to predict the environmental outcome, given a change in the design of human technology.
5. Describe, identify, and/or select information needed to support an explanation.
6. Identify or describe relevant aspects of the problem that given design solutions for reducing the impacts of human activities on the environment and biodiversity, if implemented, will resolve or improve.
7. Using given information about the effects of human activities on the environment and biodiversity, select or identify criteria against which the solution should be judged.
8. Using given information about the effects of human activities on the environment and biodiversity, select or identify constraints that the solution must meet.
9. Evaluate the criteria and constraints, along with trade-offs, for a proposed or given solution to resolve or improve the impact of human activities on the environment and biodiversity.
10. Using given data, propose a potential solution to resolve or improve the impact of human activities on the environment and biodiversity.
11. Using a simulator, test a proposed solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes.
12. Evaluate and/or revise a solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes

<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>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• <u>Students do not need to know:</u>
  • How to develop or analyze computer simulations and mathematical models that emulate the flocking behavior of animals.
  • Individual genes or complex gene interactions determining individual animal behavior.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Behavioral ecology, cooperative behavior, altruism, environmental stimuli, circadian clock, communication, foraging, optimal foraging model, energy costs and benefits, competition, predator, mutual protection, packs</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Fixed action pattern, pheromones, innate behavior, learning, imprinting, spatial learning, social learning, associative learning, problem solving, cognition, game theory, agonistic behavior, mating behavior, mating systems, parental care, mate choice, male competition for mates, reciprocal altruism, shoaling</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-8:
• Several hundred naked mole rats are observed living together in a colony. However, only one large naked mole rat is observed reproducing, while the others in the colony bring her food.
• A worker bee is observed flying away from its colony. Upon returning many other worker bees crowd around him while he moves in a distinct pattern.
• A lioness charges toward a large herd of galloping zebra, but then stops and runs away in the opposite direction.
• A certain species of short-horned grasshoppers changes color, band together, and fly over several square kilometers over a period of a few weeks.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
</table>

1. Based on the provided data, identify, describe, or construct a claim regarding how specific group behavior(s) can increase an individual's or species' chances of surviving and reproducing.
2. Sort inferences about the effect of specific group behaviors on an individual's and species' chances to survive and reproduce into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification.
3. Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.*
4. Construct an argument using scientific reasoning, drawing on credible evidence to explain the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
5. Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
6. Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.**

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD6 – summarize is the emphasis here. Avoid identify and organize.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Ask questions that arise from examining models or a theory to clarify relationships.</td><td>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)

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.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements:
• At this level, the study of inheritance is restricted to Mendelian genetics, including dominance, codominance, incomplete dominance, and sex-linked traits.
• Focus is on expression of traits on the organism level and should not be restricted to protein production.

Content Limits:
• Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.
• Assessment does not include mutations or species-level genetic variation including Hardy-Weinberg equilibrium.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Genome, zygote, fertilization, dominant, recessive, codominance, incomplete dominance, sex-linked, allele, sequencing, pedigree, parent generation, F1, F2, haploid, diploid, replication.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Epigenetics, interphase, prophase, metaphase, anaphase, telophase, cytokinesis, epistasis.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS3-1:
• DNA sequencing shows that all people have the gene for lactase production, but only about 30% of adults can digest milk.
• Polydactyl tabby cat Jake holds the world record for most toes, with seven toes on each paw.</td></tr>
</table>

	• *E. coli* bacteria are healthful in mammalian intestines but makes mammals sick when ingested. • *E. coli* bacteria are used to produce human insulin.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
8. Identify or construct an empirically testable question based on the phenomenon that could lead to design of an experiment or model to define the relationships between the role of DNA and/or chromosomes in the inheritance of traits.*	
9. Assemble or complete, from a collection of potential model components, an illustration, or pedigree that is capable of representing the role of genetic material in coding the instructions for inheritance.*	
10. Construct a question that arises from examining a model or theory to clarify the connections between DNA/chromosomes and inheritance of traits.*	
11. Make predictions about the pattern of inheritance based on a model derived from the empirically testable question. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.	
12. Assemble or complete a flow chart describing the cause and effect relationships between genetic material and the characteristic traits passed from parents to offspring.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development

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	**Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated knowledge.	**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, they 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 to make claims about specific causes and effects.

Clarifications and Content Limits	**Clarification Statements**
	• Emphasis is on using data to support arguments for the way variation occurs.
	• Inheritable traits should be traits that can be passed down through more than one generation.
	• Inheritable traits for this PE do not include dominant/recessive traits.
	• Examples of evidence for new genetic combinations and viable errors can include:
	    • karyotype comparison between parents and children;
	    • DNA sequence comparison.
	
	Content Limits
	• Assessment does not include assessing meiosis or the biochemical mechanism of specific steps in the process.
	• <u>Students do not need to know</u>: bioinformatics, specific genetic disorders.		

Science Vocabulary Students Are Expected to Know	Amino acid, DNA, enzyme, protein synthesis, chromosome, egg, egg cell, sperm, sperm cell, dominant trait, recessive trait, recombination, sex cell, sex chromosome, sex-linked trait, meiosis, mutation, advantageous, expression, base pairs, genome, UV radiation, triplet codon, insertion, deletion, frameshift, substitution, somatic, epigenetic.		
Science Vocabulary Students Are Not Expected to Know	Polyploidy, single nucleotide polymorphisms (SNPs), conjugation, DNA polymerase, mutagenic, chromosomal translocation, missense, nonsense, nongenic region, tautomerism, depurination, deamination, slipped-strand mispairing, Sheik disorder, prion, epidemiology.		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-LS3-2: • Due to pesticide residue, frogs have extra, non-functioning, limbs. • Most chickens have feathers that lay flat against their bodies. In one family of chickens, 50% of offspring have feathers that curl away from their bodies.		

	• A single gene mutation accounts for the blue color of irises in over 99.5% of people with blue eyes. • One sunflower growing in a field has a wide, flat stem and an unusual number of leaves. The next year, several sunflowers in the field share these traits.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data, make or construct a claim regarding inheritable genetic variations that may result from: 1) new genetic combinations through meiosis, 2) viable errors occurring during replication, and/or 3) mutations caused by environmental factors. This *does not* include selecting a claim from a list.
2. Sort inferences about inheritable genetic variation into those that are supported by the data, contradicted by the data, outliers in the data, or none of these—or some similar classification.
3. Identify patterns of information/evidence in the data that support correlative/causative inferences about inheritable genetic variation.
4. Construct an argument using scientific reasoning that draws on credible evidence to explain how 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. (Hand scored CR)
5. Identify additional evidence that would help clarify, support, or contradict a claim or causal argument.
6. Identify, describe, and/or construct alternate explanations or claims, and cite the data needed to distinguish among them.
7. Predict outcomes of genetic variations, given the cause-and-effect relationships of inheritance.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS3-3
Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting 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>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.</td><td>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).</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.
• Sensitivity and precaution should be used around the use of both lethal recessive and dominant human traits (i.e., Huntington’s, achondroplasia, Tay-Sachs, cystic fibrosis).

Content Limits
• Assessment is limited to basic statistical and graphical analysis.
• Assessment does not include Hardy-Weinberg calculations ($p^2 + 2pq + q^2 = 1$ or $p + q = 1$).
• <u>Students do not need to know:</u> pleiotropy, meiosis, specific names of genetic disorders.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Gene, allele, dominant, recessive, homozygous, heterozygous, phenotype, genotype, P generation, F_1 generation, F_2 generation, complete dominance, incomplete dominance, codominance, pedigree, carrier, fertilization, sex linked traits, gamete, Mendelian genetics, zygote, haploid, diploid, epistasis.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Test-cross, monohybrid, dihybrid, law of independent assortment, law of segregation, pleiotropy, norm of reaction, multifactorial, Barr Body, genetic recombination, latent allele.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS3-3:
• O Positive is the most common blood type. Not all ethnic groups have the same mix of these blood types. Hispanic people, for example, have a relatively high number of O’s, while Asian people have a relatively high number of B’s.
• Hydrangea flowers of the same genetic variety range in color from blue-violet to pink, with the shade and intensity of color depending on the acidity and aluminum content of the soil.
• Most humans were born with five fingers on each hand, yet the polydactyl trait (having more than five fingers on each hand) is the dominant trait.
• When a red rose is crossed with a white rose, all pink roses are produced.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
</table>

1.	Describe data or patterns/relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population, due to both genetic and environmental factors.*
2.	Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of both genetic and environmental factors.*
3.	Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the relationship between a trait's occurrence in a population and genetic and environmental factors.
4.	Analyze, evaluate, estimate, calculate, and/or construct an equation for the statistical mean and/or the standard deviation, to describe the change in the distribution of a trait in a population over time, due to genetic and environmental factors.*
5.	Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (norm reaction), which may or may not be quickly removed due to genetic and environmental factors.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

Performance Expectation	**HS-LS4-1** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.		
Dimensions	**Obtaining, Evaluating, and Communicating Information** • 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).	**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.	**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.
Clarifications and Content Limits	**Clarification Statements** • 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. **Content Limits** • <u>Students do not need to know</u>: specific genetic mutations, specific genetic disorders, specific proteins, Occam's razor (maximum parsimony), formation of orthologous and paralogous genes, molecular clock, Neutral theory.		
Science Vocabulary Students are Expected to Know	Amino acids, cladogram, comparative anatomy, DNA sequencing, electrophoresis, embryology, evolution, fossil record, gene flow, genetic drift, mutation, natural selection, nucleotides, sedimentary layers, species, descent with modification, homologous structures, evolutionary tree, analogous structures.		
Science Vocabulary Students are Not Expected to Know	Phylogenetic, phylogeny, phylogenetic tree, taxonomy, cladistics, vestigial structures, convergent evolution, analogous, endemic, phylocode, sister taxa, basal taxon, polytomy, homoplasy, molecular systematics, monophyletic, parphyletic, polyphyletic, maximum parsimony, orthologous genes, paralogous genes, horizontal gene transfer.		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-LS4-1: • Red pandas look a bit like bears and a bit like raccoons. Task Statement: Provide evidence about whether red pandas are better classified as raccoons or bears. Stimulus material might include pictures, DNA information, embryological information, and homologous structures. • Hermit crabs live in shells, like oysters, but look like crabs. Provide evidence classifying hermit crabs either as mollusks (like oysters) or arachnids (like crabs). • Crawfish look just like lobster, but smaller. Which came first, the lobster or the crawfish? • Fossil records of an extinct hooved animal show a thickened knob of bone in its middle ear. This structure is also found in modern whales and helps them hear underwater.		

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that support common ancestry among organisms and/or biological evolution.*
2. Evaluate the validity/relevance/reliability of scientific evidence about biological evolution.
3. Identify relationships or patterns in scientific evidence at macroscopic and/or microscopic scales.*
4. Describe the specific evidence needed to support an explanation about how organisms share a common ancestor.
5. Synthesize an explanation that incorporates the scientific evidence from multiple sources.

*denotes those task demands which are deemed appropriate for use in stand-alone item 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>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct 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>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 to make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.
• Students do not need to know: Hardy-Weinberg equation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Beneficial change, detrimental change, distribution, emergence, gene frequency, biotic, abiotic, advantageous, diverge, proliferation, bottleneck effect, island effect, geographic isolation, founder effect, recombination.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Hardy-Weinberg equilibrium, biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency-dependent selection, prezygotic barriers, postzygotic barriers.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/</td><td colspan="3">Some example phenomena for HS-LS4-2:</td></tr>
</table>

Phenomena	• Cane toads introduced to Australia in the 1930s have evolved to be bigger, more active, and have longer legs. • In the late 1990s, a resurgence of bedbug outbreaks began. Bedbugs are now much harder to kill with thick, waxy exoskeletons, faster metabolism, and mutations to block certain insecticides. • Skinks living in cooler regions give live birth, while those living in warm coastal areas lay eggs. • A butterfly parasite found on the Samoan Islands destroyed the male embryos of blue moon butterflies, decreasing the male population to only 1%. After a year, males had rebounded to 40% of the population.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Describe the cause-and-effect relationship between: (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, and change in species over time. This may include indicating directions of causality in a model or completing cause-and-effect chains.
2. Describe, identify, or select evidence supporting or contradicting a claim about the role of (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 in causing the phenomenon. The evidence may be evidence generated by the students in the simulation or selected from provided data.
3. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.
4. Use evidence to construct an explanation of the changes in species over time as a result of (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.***(SEP/DCI/CCC)**
5. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses for the changes in species over time.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<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>Dimensions</td><td>Analyzing and Interpreting 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. The differential survival and reproduction of organisms in a population that have an advantageous heritable trait lead 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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.

Content Limits
• Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.
• <u>Students do not need to know</u>: sexual selection, kin selection, artificial selection, frequency-dependent selection.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Fitness, gene, allele, directional selection, diversifying (disruptional selection), stabilizing selection, standard deviation, vestigial structure.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Hemizygous, aneuploidy, intragenomic conflict, sexual dimorphism, balanced polymorphism, apostatic selection.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Example phenomena for HS-LS4-3:</td></tr>
</table>

	• Green Treefrogs (*Hyla versicolor*) are abundant in the wetlands of Florida where no Gray Treefrogs (*Hyla cinerea*) are observed. In the wooded areas of New York, only Gray Treefrogs are observed. • In the Amazon rainforest, a kapok trees (*Ceiba pentandra*) measures 200 feet in height, approximately 30 feet above the rest of the canopy. • A school of mummichog fish (*Fundulus heteroclitus*) is found in the 6°C waters of the Chesapeake Bay. These fish are normally found in warmer climates, like the 21°C waters of Kings Bay, Georgia. • A population of the fish *Poecilia mexicana* lives in the murky hydrogen-sulfide (H2S)-rich waters in southern Mexico that would kill the same species of fish living in clear freshwaters only 10 km away.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Describe or identify patterns or relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population due to natural selection/selection pressure(s).*
2. Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of selection pressure(s) in the environment (including Hardy-Weinberg-based predictions about changes in allele/trait frequency/magnitude NOT based on calculations).*
3. Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the effect of selection on a population.
4. Analyze, evaluate, estimate, calculate, and/or construct an equation to describe the change in the distribution of a trait in a population over time due to selection pressure(s).
5. Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (for example, Joe DiMaggio's hitting streak, tossing 10 consecutive heads on a fair coin, etc.) which may or may not be quickly removed due to selection pressure.
6. Use statistical analysis to calculate changes in traits in a population over time to provide evidence for an explanation of the relationship between a trait's occurrence and its prevalence in the population at different points in time.
7. Identify explanations for a change in a traits frequency and/or distribution in a population over time that can be supported by patterns or relationships in data.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-4
Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• 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. The differential survival and reproduction of organisms in a population that has 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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• 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.

Content Limits
• Assessment does not include the Hardy-Weinberg equation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Beneficial change, detrimental change, distribution, emergence, gene frequency, gene, biotic, abiotic, advantageous, diverge, proliferation, sexual reproduction, bottleneck effect, island effect, geographic isolation, gene flow, genetic drift, founder effect.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Hardy Weinberg Equilibrium, biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency-dependent selection, prezygotic barriers, postzygotic barriers.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS4-4:
• Following a four-year drought in California, field mustard plants are found to flower earlier in the season.
• A new antibiotic is discovered. Within ten years, many bacterial diseases that were previously treated by the antibiotic no longer respond to treatment (e.g., MRSA).
• A small population of Italian wall lizards that feed mainly on insects is introduced to a neighboring island. After several decades, the lizards are found to have thrived and heavily populated the island, and their diet is now mostly vegetation.
• Following climatic changes, the European Great Tit bird begins laying eggs earlier in the spring.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Organize or summarize the given data or evidence of population characteristics, environmental characteristics, and/or the relationships between them.
2. Generate or construct graphs or tables of data to highlight patterns within the given data.
3. Describe the cause and effect relationship between natural selection and adaptation using evidence. This may include assembling descriptions from illustrations or lists of options and distractors, or indicating directions of causality in a model or completing cause and effect chains.
4. Describe, identify, or select evidence supporting or contradicting a claim about the role of adaptation in causing the phenomenon. The evidence may be generated by the students in a simulation.
5. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.
6. Use evidence to construct an explanation of the adaptation of a species through natural selection. Evidence can be described, identified, or selected/assembled from lists with distractors. Explanations can be written, assembled by manipulating the components of a flow chart or model, or assembled from lists of options that include distractors. Options and distractors should not be single words or short phrases; rather, they should be complete thoughts that, when correctly emplaced within a sentence or paragraph, work to provide evidence of a coherent train of thought.*
7. Identify and justify additional pieces of evidence that would help distinguish among competing hypotheses.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.</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 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.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• <u>Students do not need to know</u>: Hardy Weinberg Equation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Beneficial change, detrimental change, distribution, emergence, gene frequency, biotic, abiotic, advantageous, diverge, mutation, proliferation, bottleneck effect, island effect, geographic isolation, founder effect, recombination, microevolution, gene flow, speciation, hybrid</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency dependent selection, prezygotic barriers, postzygotic barriers, average heterozygosity, cline, sexual selection, sexual dimorphism, intrasexual selection, intersexual selection, neutral variation, balancing selection</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS4-5:
• PCB pollution in the Hudson River wiped out many fish species, but the Atlantic tomcod thrives there (results 1 and 3).
• The population of Greater Prairie Chickens in Illinois decreased from millions of birds in the 1800s to fewer than 50 birds in 1993 (result 3).
• In 1681 the dodo bird went extinct due to hunting and introduction of invasive species (result 3).
• In 1988, the Orange-Spotted Filefish went extinct in response to warmer ocean temperatures (result 3).</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
</table>

1. Based on the provided data, identify, describe, or construct a claim regarding the effect of changes to the environment on the (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.
2. Sort inferences about the effect of changes to the environment on (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 into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification.*
3. Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of changes to the environment on the (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.*
4. Construct an argument and/or explanation using scientific reasoning drawing on credible evidence to explain the effect of changes to the environment on the (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.
5. Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of changes to the environment on the (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.
6. Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of changes to the environment on (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.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<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>Dimensions</td><td>Using Mathematics and Computational Thinking
• 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.

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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
• The simulation should model the effect of human activity and provide quantitative information about the effect of solutions on threatened or endangered species or to genetic variation within a species.

Content Limits
• <u>Students do not need to know</u>: Calculus/advanced mathematics (e.g., exponential growth and decay)</td></tr>
</table>

<table>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td>Anthropogenic, efficient, overexploitation, urbanization, acidification, deforestation, concentration, radiation, greenhouse gas, surface runoff, civilization, consumption, mass wasting, urban development, per-capita, degradation, pollutant, best practice, cost-benefit, extract, regulation</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td>Oligotrophic and eutrophic lakes/eutrophication, littoral zone, exponential population growth, logistic population growth, ecological footprint, ecosystem services, extinction vortex, minimum viable population, effective population size, critical load.</td></tr>
<tr><td colspan="2" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td>Some example phenomena for HS-LS4-6:
The habitat of the Florida Panther is only 5% of its former range, causing the species to become endangered.
The café marron plant is critically endangered due to massive habitat destruction on the Island of Rodrigues in the Indian Ocean, as a result of deforestation for agricultural use.
The population of Atlantic Bluefin Tuna has declined by more than 80% since 1970 due to overfishing.
In the past 120 years, about eighty percent of suitable orangutan habitat in Indonesia has been lost from expansion of oil palm plantations. At the same time, the estimated number of orangutans on Borneo, an island in Indonesia, has declined from about 230,000 to about 54,000.</td></tr>
<tr><td colspan="2" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2" align="center">Task Demands</td></tr>
<tr><td colspan="2">1. Use data to calculate or estimate the effect of a solution on mitigating the adverse impacts of human activity on biodiversity.</td></tr>
<tr><td colspan="2">2. Illustrate, graph, or identify features or data that can be used to determine how effective a solution is for mitigating the adverse impacts of human activity on biodiversity.</td></tr>
<tr><td colspan="2">3. Estimate or infer the properties or relationships that lead to mitigation of the adverse impacts of human activity on biodiversity, based on data.</td></tr>
<tr><td colspan="2">4. Compile the data needed for an inference about the impacts of human activity on biodiversity. This can include sorting out the relevant data from the given information.</td></tr>
<tr><td colspan="2">5. Using given information, select or identify the criteria against which the solution should be judged.</td></tr>
<tr><td colspan="2">6. Using a simulator, test a proposed solution and evaluate the outcomes; may include proposing modifications to the solution.*</td></tr>
</table>

*In order to satisfy this PE, the student <u>must</u> use a simulator. Therefore, this task demand must always be used.

<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 that eventually reaches Earth in the form of radiation.</td></tr>
<tr><td>Dimensions</td><td>Developing and using models
• 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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include details of the atomic and sub-atomic processes involved with the sun’s nuclear fusion.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">sunspot cycle, solar maximum, solar minimum, sunspots, solar flares, UV radiation, IR radiation, convection, nuclear fusion, core, atmosphere, solar storm, luminosity</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">photosphere, chromosphere, corona, coronal mass ejections</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS1-1:
• The habitable zone in our solar system currently contains both Earth and Mars. In the future it will contain a different set of planets.
• The sun's current surface temperature is about 5,800 K. In 5 billion years, the sun's surface temperature will cool to 3,500 K.
• The sun is 40% brighter, 6% larger than 5% hotter than it was 5 billion years ago.
• The Earth’s atmosphere will contain more water vapor and the oceans will contain less water in a few billion years.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), summarize or make inferences about data to highlight trends, patterns, or correlations.</td></tr>
</table>

2. Identify patterns or evidence in the data that supports inferences about the lifespan of the sun or the transfer of energy from the sun to the earth.
3. Select or identify from a collection of potential model components, including distractors, the components needed for a model that illustrates the lifespan of the sun or the transfer of energy from the sun to the earth.
4. Construct or complete a model capable of illustrating the lifespan of the sun or the transfer of energy from the sun to the earth.
5. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that are relevant to the lifespan of the sun or the transfer of energy from the sun to the earth.
6. Identify missing components, relationships, or other limitations of the model.
7. Make predictions about the effects of changes in the sun or in the transfer of energy from the sun to the earth. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• 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.</td><td>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)</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the astronomical evidence of the redshift 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).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Recessional velocity, galaxy, star, galaxy cluster, spectrum, spectra, wavelength, frequency, Doppler Effect, redshift, blueshift, light years, big bang theory, helium, emission, absorption</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Cosmological redshift, Hubble Law, photometric redshift, spectroscopy</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example Phenomena for HS-ESS1-2:
• The farthest known galaxy has a greater recessional velocity than the farthest known quasar.</td></tr>
</table>

	• The spectrum of NGC450 shows a greater abundance of elements heavier than helium than does the spectrum of NGC60 • Two galaxy clusters observed in opposite parts of the sky both contain galaxies with about the same chemical composition: 75% hydrogen and 25% helium. • A galaxy in the constellation Cetus is moving away from us at a different speed than another galaxy in the adjacent constellation Pisces.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.	
2. Identify evidence that supports and/or does not support the Big Bang Theory.	
3. Describe, select, or identify components of the Big Bang Theory supported by given evidence.	
4. Use an explanation of the Big Bang Theory to predict how the universe will continue to change over time.	
5. Construct an explanation based on evidence that explains how particular aspects of the Big Bang Theory are supported by empirical observations of the universe.	
6. Identify and justify additional pieces of evidence that would help distinguish among competing hypotheses.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-3
Communicate scientific ideas about the way stars, over their life cycle, produce elements.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• 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).</td><td>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.</td><td>Energy and Matter
• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.
• Include basic/simplified nucleosynthesis reactions:
  • Hydrogen fuses into helium
  • Helium fuses into carbon
  • Carbon fuses into oxygen
  • Oxygen fuses into silicon
  • Silicon fuses into iron
• Exclude complex nucleosynthesis reactions and details:
  ○ CNO cycle
  ○ Neutron-capture (r-process and s-process)
  ○ Proton-capture: Rp-process
  ○ Photo-disintegration: P-process
  ○ Other details about radiation or particles – focus on conservation of nucleons</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">main sequence, nucleosynthesis, nuclear reactions, fission, fusion, nucleons, proton, neutron, , , gamma rays, neutrinos, red giant, blue giant, white dwarf, planetary nebular, supernova, supernova remnant, globular cluster, open , exothermic reactions, endothermic reactions, emissions spectrum, absorption spectrum, emission lines, absorption lines, H-R Diagram</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Neutron-capture, proton-capture, photo-disintegration, CNO cycle, radiogenesis</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomenon for HS-ESS1-3:</td></tr>
</table>

<table>
<tr><td></td><td>• Two larger stars, Spica and Pollux are eight times larger than the sun. However, Spica is 420 times brighter and 6 times more massive than Pollux.
• Procyon is a 1.5 solar mass star and is 8 times brighter than the sun. Aldebaran is a star of similar mass but Aldebaran is 425 times brighter than the sun.
• The stars in a globular cluster (old low mass stars) are red and show few absorption lines in their spectra while the stars in an open cluster (young high mass stars) are blue and show many absorption lines in their spectra.
• In the core of some stars, carbon can fuse into neon, sodium or magnesium.</td></tr>
<tr><td colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2">Task Demands</td></tr>
<tr><td colspan="2">1. Illustrate, model or make calculations involving the nucleosynthesis process in stars of different mass, different luminosity, different age or different evolutionary stage using graphs, diagrams, text and mathematical models.</td></tr>
<tr><td colspan="2">2. Compare and contrast the nucleosynthesis processes of stars of different mass, different luminosity, different age or different evolutionary stage using graphs, diagrams, text and mathematical models.</td></tr>
<tr><td colspan="2">3. Make predictions about nucleosynthesis processes given changes or differences in other stellar characteristics.</td></tr>
<tr><td colspan="2">4. Identify and communicate evidence supporting an explanation regarding the relationship between stellar properties and age, in particular how those stellar properties change over time.</td></tr>
<tr><td colspan="2">5. Synthesize an explanation regarding the relationship between stellar properties and age, in particular how those stellar properties change over time.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-4
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical or computational representations of phenomena to describe explanations.</td><td>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.</td><td>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).</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets, moons, rings, asteroids, and comets.
• The term "satellite" can be used to describe both man-made and natural objects that orbit another object.

Content Limits
• Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with systems of more than two bodies, nor involve calculus.
• Comparing different orbiting bodies is acceptable as long as each system only contains two bodies (example: satellite 1 orbiting Earth compared to satellite 2 orbiting Earth).
• Students will be given the Law of Gravitation to make calculations but should know/apply Kepler's laws conceptually. These laws are:
1. Orbits are elliptical;
2. Line connecting orbiting body and parent body sweeps out equal areas in equal time;
3. (Orbital period)^2 is proportional to (semi-major axis distance)^3.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Gravitation, orbit, revolution, rotation, period, semi-major axis, eccentricity, semi-minor axis, focus, foci, ellipse, gravitational constant, astronomical unit, satellite</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Aphelion, perihelion, angular momentum</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some sample phenomena for HS-ESS1-4:
• The International Space Station orbits Earth at an altitude of 250 miles with a speed of 5 miles per second while a global positioning system satellite orbits ten times as far and half as fast.
• China's Tiangong space station's orbital speed can no longer be controlled. It is expected to burn up in the atmosphere as it falls to the Earth.
• The shape of Comet Shoemaker-Levy 9's orbit changed just before it collided with Jupiter in 1994.</td></tr>
</table>

	• In 100 years, the moon will be about half a meter further from Earth and Earth's rotation will be 2 miliseconds slower.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Make simple calculations using given data to calculate or estimate the motion of orbiting objects (satellites).	
2. Illustrate, graph, or identify relevant features or data that can be used to calculate, estimate or make inferences about the motion of satellites.	
3. Calculate or estimate properties of motions for a satellite and the object it orbits based on data from one or more sources.	
4. Select or construct relationships between a satellite and the object it orbits based on data from one or more sources.	
5. Compile, from given information, the particular data needed for a particular inference about the motion of a satellite. This can include sorting out the relevant data from the given information.	
6. Construct or identify an inference that can be made based on data from one or more sources.	

Performance Expectation	**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.		
Dimensions	**Engaging in Argument from Evidence** • Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**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. *(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)*	**Patterns** • Empirical evidence is needed to identify patterns.
Clarifications and Content Limits	**Clarification Statements** • 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). **Content Limits** • Students do not need to calculate radioactive decay rates. • <u>Students do not need to know:</u> names of supercontinents, names of fault lines, names of tectonic plates		
Science Vocabulary Students are Expected to Know	Convergence, divergence, sedimentary, metamorphic, igneous, volcanic, crust, mantle, core, mid ocean ridge, trench		
Science Vocabulary Students are Not Expected to Know	Isotope, anticline, syntacline		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-ESS1-5: • Rocks near Bildudalur Iceland were formed about about 16 million years ago, rocks near Geysir Iceland were formed about 3.3 million years ago. • The patterns of magnetic reversals on the youngest continental rock columns are the same as the pattern of magnetic reversals found at the center of the Mid-Atlantic ridge. • Iceland gains about 1.8 centimeters of land surface per year.		

	• From 1996 to 2016, Mount St. Elias has gotten 0.08 meters taller.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data or information, identify the explanation that could explain the age difference in continental and oceanic crust.
2. Identify and/or explain the claims, evidence, and reasoning supporting the explanation that tectonic plates have moved over time.
3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the movement of tectonic plates and/or the ages of rocks.
4. Evaluate the strengths and weaknesses of a claim to explain the theory of plate tectonics and the ages of rocks.
5. Analyze and/or interpret evidence and its ability to support the explanation that plate tectonics or radioactive decay can determine the age of a rock.
6. Provide and/or evaluate reasoning to support the explanation that volcanoes, mountains and earthquakes are formed/caused as a result of plate tectonics

<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>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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>Science Vocabulary Students are Expected to Know</td><td colspan="3">Plate tectonics, radiometric dating, isotope, continental crust, oceanic crust, lithosphere, asthenosphere, cycle, bedrock, ocean trench, sedimentation, convection current, ancient core, inner core, mantle, nuclear, ocean ridge, sea-floor spreading</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Nebular hypothesis, planetesimals, solar nebula, bolide impacts,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some sample phenomena for HS-ESS1-6:
• A thin section of a rock from western Australia is examined under a microscope and elongate crystals are observed.
• A rock from Earth and a rock from Mars are the same age.
• When astronauts returned to Earth with rocks from the moon, they were all very old. A rock found in the Great Lakes Region of North America is very old, but rock found in Iceland are all relatively young. Meteor Crater is a large depression, with a depth of 170m, in an otherwise flat area of Arizona.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
</table>

2. Express or complete a causal chain explaining Earth's formation and/or early history. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Describe, identify, and/or select information needed to support an explanation about the formation of Earth and its early history.
5. Construct an explanation based on evidence and scientific reasoning that explains the formation of Earth and its early history. *****

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<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>Dimensions</td><td>Developing and Using Models
• 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 of continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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).

Content Limits
• <u>Students do not need to know:</u> the details of the formation of specific geographic features of Earth's surface.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Tectonic uplift, seismic waves, feedback effect, irreversible, Earth's magnetic field, electromagnetic radiation, inner core, outer core, mantle, continental crust, oceanic crust, sea-floor spreading, isotope, thermal convection, radioactive decay, rock composition, continental boundary, ocean trench, recrystallization, nuclear, geochemical reaction, mass wasting</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Geomorphology, anticline, syncline, monocline</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some sample phenomena for HS-ESS2-1:
• A limestone cliff that contains Cambrian-aged fossils extends several hundred feet above the surface of the ocean. A large section of the cliff has collapsed.
• An oceanic trench 10,000 is meters below sea level. Inland, 200km away, a chain of active volcanoes is present.
• 1.8 billion year old rocks in the Black Hills of South Dakota are capped by 10,000 year old gravel terraces.
• A photograph from March shows large Precambrian-aged pink granite boulder at the top of a 100 m tall hill. A photograph in April shows the same boulder sitting in a pile of soil and sediment in the valley below the hill.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include different rock types, rates of uplift and erosion, surface environments on Earth where these processes occur and where different rock types exist, and layers within Earth where these processes occur. Sources of energy (radiation, convection) that drive the cycling (but *not* the creation of) matter should also be included as components.*	
2. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of Earth's internal and surface processes.	
3. Make predictions about the effects of changes in the magnitude and/or rate of Earth's internal and surface properties. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.	
4. Given models or diagrams of land features, internal and surface processes, identify factors that affect constructive and destructive forces, feedback effects and how they vary in different scenarios OR identify the constructive and destructive mechanisms that operate at different spatial and temporal time scales and how this causes changes in the appearance of continental and ocean-floor features.	
5. Identify missing components, relationships, or other limitations of the model of how Earth's internal and surface processes form continental and ocean-floor features.	
6. Describe, identify, or select the relationships among components of a model that describe the formation of continental and ocean-floor features with respect to spatial and temporal variability in internal and external surface processes or explains how changes in these processes affect the formation of continental and ocean-floor features.*	
7. Express or complete a causal chain explaining how changes in the flow of energy (interval vs. surface processes) affect the formation of continental and ocean-floor features. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.	

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<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 Earth's systems.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using tools, technologies and/or models (e.g. computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design.</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 the 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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples should include climate feedbacks, such as:
  • 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.
  • Loss of ground vegetation causes an increase in water runoff and soil erosion
  • Damned rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion
  • Loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.

Content Limits
• <u>Students do not need to know:</u>
  o Specifically which gases are greenhouse gases.
  o Composition of the atmosphere</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Ocean circulation, biosphere, feedback effect, atmospheric circulation, convection cycle, greenhouse gas, geoscience, sea level, mean surface temperature, methane</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Electromagnetic radiation, probabilistic, irreversible, geoengineering, ozone, pollutant, acidification</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-2:
• Farming causes the loss of forest in the Amazon. This leads to an increase in erosion and water runoff, which leads to more forest loss.
• Loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.
• As the Permafrost in the Artic melts, methane is released into the atmosphere. Methane, a greenhouse gas, traps heat causing the Earth to heat up, leading to more Permafrost melting.</td></tr>
</table>

	• Increased CO_2 in the atmosphere warms the oceans. Warmer oceans take up less CO_2 than cooler oceans, further increasing atmospheric temperature.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in how changes to Earth's surface can create feedbacks that affect Earth's systems.	
2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in how changes to Earth's surface can create feedbacks that affect Earth's systems. This may include sorting out distractors.	
3. Use relationships identified in the data to predict how changing the Earth's surfaces affects the feedback loop.	
4. Identify patterns or evidence in the data that supports inferences about how the altering of Earth's surface will affect the Earth in the long term.	

Performance Expectation	**HS-ESS2-3** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.		
Dimensions	**Develop and Using Models** • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**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. **PS4.A: Wave Properties** • Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet *(secondary)*	**Energy and Matter** • Energy drives the cycling of matter within and between systems.
Clarifications and Content Limits	**Clarification Statements** • 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.		
Science Vocabulary Students are Expected to Know	Convection, radioactive, inner core, outer core, isotope, mantle, seismic wave, Geochemical reaction, geoscience, molten rock, Earth's elements, Earth's internal energy sources, geochemical cycle, tectonic uplift		
Science Vocabulary Students are Not Expected to Know	Geoneutrino, primodial heat		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-ESS2-3: • The temperature of the water in a hot spring in Iceland is around 100°F. The average air temperature in Iceland is about 52°F.		

	• The average heat flow from the Earth's interior is 80 mWm^{-2}. The heat flow of a volcano on Hawaii is ~400 mWm^{-2}. • The total heat transfer from the Earth to space is 44 terawatts. Radioactive decay of unstable isotopes contributes 20 terawatts from Earth's interior. (KamLAND Collaboration, 2011). • In the central valley of California, the temperature at 5 meters below the ground is 2°C warmer than the temperature at the surface. In northern Oregon near Mt. Hood, the temperature 5 meters underground is 10°C warmer than the temperature at the surface.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include the structure of the Earth, the cycling of matter and/or energy, or instruments used to measure seismic waves.
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing the structure and the flow of matter/energy from the Earth's interior. This <u>does not</u> include labeling an existing diagram.
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
4. Make predictions about the effects of changes in the cycling of matter and energy. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Given models or diagrams of the earth's interior, identify the chemical and physical properties of the Earth's structure that cause the cycling of matter.
6. Identify missing components, relationships, or other limitations of the model.
7. Describe, select, or identify the relationships among components of a model that describe the cycling of matter within Earth's interior.

<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>Dimensions</td><td>Developing and Using Models
• Use a model to provide mechanistic accounts of phenomena.</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 Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary)

ESS2.A: Earth Materials and Systems
• The geologic record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output of Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of timescales 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 system 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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of the causes of climate change differ by time scale, 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.

Content Limits
• 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.
• <u>Students do not need to know:</u> chemical mechanisms of fossil fuel combustion or ozone depletion</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Interdependence, solar radiation, solar flare, biosphere, atmospheric circulation, ocean circulation, climatic patternsea level, glacier, atmospheric composition, hydrosphere, greenhouse gas, fossil fuel, combustion</td></tr>
<tr><td>Science Vocabulary Students are</td><td colspan="3">Acidification, cryosphere</td></tr>
</table>

Not Expected to Know	
Phenomena	
Context/ Phenomena	Some example phenomena for HS-ESS2-4: • Temperatures were warmer in 1990 than in the 5 previous years. In 1992 and 1993, the global temperatures were 1°F cooler than in 1991. (volcanic eruption of Mount Pinatubo) • 11,000 years ago large portions of the northern United States contained glaciers. Today, very little of this area contains glaciers. (changes to Earth's orbit) • Earth experiences 4 distinct seasons. Venus does not experience distinct seasons. (tilt of planet's axis) • 25,000 years ago, the level of carbon dioxide in the atmosphere was around 180 parts per million (ppm). Today, carbon dioxide levels exceed 400 ppm. (atmospheric composition)
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include factors that affect the input, storage, redistribution, and output of energy in Earth's systems.	
2. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of the flow of energy in Earth's systems.	
3. Make predictions about the effects of changes in energy flow on Earth's climate.	
4. Given models or diagrams of energy flow in Earth's systems, identify factors that affect energy input, output, storage, and redistribution and how they change in different scenarios OR identify the changes in energy flow that cause changes in Earth's climate.	
5. Identify missing components, relationships, or other limitations of the model of energy flow in Earth's systems.	
6. Describe, identify, or select the relationships among components of a model that describe changes in the flow of energy in Earth's systems or explains how changes in energy flow affect climate.	
7. Express or complete a causal chain explaining how changes in the flow of energy in Earth's systems affects climate. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-5
Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., the 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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide evidence for the 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, and 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).

Content Limits
• 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></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Viscosity, melting point, freezing point, absorption, dissolve, hydrologic cycle, rock cycle, stream transportation, stream deposition, stream table, erosion, soil moisture content, frost wedging, chemical weathering, solubility, mechanical erosion, heat capacity, density, molecular structure, sediment, cohesion, polarity.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3"></td></tr>
<tr><td colspan="4">Phenomena</td></tr>
</table>

Context/ Phenomena	Some example phenomena for HS-ESS2-5: • In a cave in Guam, sections of stalactites that formed during seasons of high rainfall contain a lower ratio of the isotopes oxygen-18 to oxygen-16 than sections of the stalactites that formed during seasons of low rainfall. • Wookey Hole Caves have about 4,000 meters of cave system in a rock formation. • The Colorado River runs through the rock formation known as the Grand Canyon.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify from a list, including distractors, the materials/tools needed for an investigation of the properties of water and its effects on Earth’s materials and surface processes.
2. Identify the outcome data that should be collected in an investigation of the properties of water and its effects on Earth’s materials and surface processes.
3. Evaluate the sufficiency and limitations of data collected to explain the effects of water on Earth’s materials and surface processes.
4. Make and/or record observations about the chemical and/or physical properties of liquid water and its effects on Earth’s materials.
5. Interpret and/or communicate the data from an investigation of the effect of water on Earth’s materials and surface processes.
6. Explain or describe the causal processes that lead to the observed effects of water.
7. Select, describe, or illustrate a prediction made by applying the findings from an investigation of the effects of water on Earth’s materials and surface processes.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-6
Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>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.</td><td>Energy and Matter
• The total amount of energy and matter in closed systems is conserved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• <u>Students do not need to know:</u> How to calculate the residence time by dividing the reservoir size by the flow rate, either in or out; how to calculate the biomass in a given ecosystem.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Concentration, rate of transfer/flow, pathway, hydrosphere, geosphere, biosphere, reservoir, sink, basin, pool, accumulate, biomass, equilibrium, chemosynthesis, byproduct, element, hydrocarbon, organic, inorganic, biotic, abiotic, diffusion, decompose, decay, microbe, fungi, bacteria, sediments, sequestered</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">assimilation, residence time, facies, orogenic, strata, outgassing, LeChatelier’s Principle</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-6:
• Data indicates that higher levels of atmospheric carbon dioxide increase both carbon's input and release from the soil.
• Even though trees take up carbon dioxide from the atmosphere, scientists find little carbon accumulation in the soil of a North Carolina forest.
• Human activity releases more than 30 billion tons of carbon dioxide into the atmosphere per year. However, scientists estimate that Earth's soil releases roughly nine times more carbon dioxide into the atmosphere than all human activities combined.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, mathematical variables, and/or mathematical operators, including distractors, the components, variables, and/or operators needed to mathematically and/or quantitatively model the phenomenon. Components and mathematical variables might include/represent organisms, spheres, molecules and/or elements, chemical, physical, and/or biological</td></tr>
</table>

	processes, and reservoirs. Operators might include symbols for addition, subtraction, multiplication, division, etc.
2.	Assemble or complete, from a collection of potential model components, mathematical variables, and/or mathematical operators, an illustration or flow chart that is capable of mathematically and/or quantitatively representing how matter and energy are continuously transferred within and between organisms and their physical environment. This does not include labeling an existing diagram.
3.	Describe, select, or identify the mathematical and/or quantitative relationships among components of a model and/or mathematical variables that describe how matter and energy are continuously transferred within and between organisms and their physical environment.
4.	Manipulate the components of a mathematical and/or quantitative model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
5.	Make predictions about the effects of changes in the rate at which materials or elements move from one reservoir or sphere to another. Predictions can be made by manipulating model components, mathematical variables, and/or mathematical formulas, completing illustrations, selecting from lists with distractors, or performing calculations given sufficient information to do so.
6.	Given mathematical and/or quantitative models or diagrams of how matter and energy are continuously transferred within and between organisms and their physical environment, identify the pathways of matter and/or energy transfer within an environment and how they change in each scenario OR identify the properties of the environment that cause changes in the transfer of matter and/or energy within that environment.
7.	Identify missing components, mathematical variables, mathematical and/or quantitative relationships, or other limitations of the mathematic and/or quantitative model.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-7
Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an oral and written argument or counter-arguments based on data and evidence.</td><td>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 co-evolution of Earth's surface and the life that exists on it.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and the Earth's 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; and 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.

Content Limits
• Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Plate tectonics, rock formation, geologic evidence, ocean basin, radioactive, rock strata, time scale, continental boundary, ocean trench, sedimentation, continental shelf, crustal deformation, crustal plate movement, fracture zone, convection, atmospheric composition, groundwater, igneous rock, metamorphic rock, sedimentary rock, water cycle, landslide, deposition, greenhouse gas, mass wasting, molten rock, surface runoff</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Ecosystem services, Anthropocene, eutrophication, ecohydrology, geomorphology, heterogeneity</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-7:
• Eospermatopteris fossils (first trees) begin to appear in rocks dated 390 million years. Fossils of Tiktaalik (four legged fish), one of the earliest land animals, are found in the rock layers above Esopermatopteris.
• The appearance of cyanobacteria is recorded in fossils that formed roughly 3.5 billion years ago. Superior Type banded iron formed roughly 1.8 to 2.7 billion years ago. It is characterized by alternating red and gray layers of iron rich minerals and silica rich minerals.
• The Rhynie Chert beds in Aberdeenshire Scotland contain detailed fossils of early plants. Bryophyte fossils from about 500 million years ago, show small simple structured plants.</td></tr>
</table>

	Cooksonia pertoni fossils from about 430 million years ago show plants that were larger, spore bearing, and contained tissues that move water through the plant (vascular). • In 2016 two-thirds of the Northern portion of the Great Barrier Reef experienced severe bleaching. The Great Barrier Reef prior to this event, was made up of corals with a variety of bright colors that attracted a variety of marine life. In 2016, the coral turned completely white and few fish inhabit the area where bleaching has occurred.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how Earth's systems coevolved simultaneously with life on Earth. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the simultaneous coevolution of Earth's systems and life on Earth. This may entail sorting relevant from irrelevant information or features.
4. Construct or identify from a collection, including distractors, an explanation based on evidence that explains how Earth's systems coevolved simultaneously with life on Earth.*
5. Describe, identify, and/or select information and/or evidence needed to support an explanation. This may entail sorting relevant from irrelevant information or features.
6. Identify patterns or evidence in the data that support conclusions about the relationship between the evolution of life on Earth and Earth's systems.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• 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>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.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• <u>Students do not need to know:</u> distribution of specific resources</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Renewable, non-renewable, mitigation, economic cost.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biome</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-1:
• In 2001, 85% of Australians lived within 50 km of the ocean.
• There are large solar power plants in the southern California desert. California solar power had a capacity of 18,296 MW in 2016. In the same year, New York State had a capacity of 927 MW.
• As many as 1.5 million inhabitants of Dhaka, Bangladesh, have moved there from villages near the Bay of Bengal.</td></tr>
</table>

	• After the eruption of Mt. Vesuvius in 79 AD, the city of Pompeii was completely buried in volcanic ash. The city was never reoccupied and was lost for more than 1,500 years.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
7. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
8. Express or complete a causal chain explaining how resource availability/natural hazards/climate change drive changes in human society/population/migration. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
9. Identify evidence supporting the inference of causation that is expressed in a causal chain.
10. Use an explanation to predict the change in human /activity given a change in resource availability/natural hazards/climate.
11. Describe, identify, and/or select information and/or evidence needed to support an explanation.
12. Construct an explanation based on evidence that explains that the availability of natural resources/occurrence of natural hazards/changes in climate have influenced human activity.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development.

<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>Dimensions</td><td>Engaging in Argument from Evidence
• 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></td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements:
• 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>Science Vocabulary Students are Expected to Know</td><td colspan="3">Renewable, non-renewable, mitigation, economic cost, irreversible, reversible, exponential, logarithmic, basin, sustainability, recycle, reuse, species, societal, wetland, groundwater, metal, consumption, per-capita, stabilize, fossil fuel, mining, conservation, extract, agriculture, timber, fertile land, solar radiation, biotic, abiotic, depletion, extinction, economics, manufacturing, technology,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-2:
• There is a tower in the middle of North Dakota with flames shooting out the top of it.
• In Pennsylvania, a match is struck next to a running water faucet and a large flame appears.
• On the Yangtze River in China, blades of an underwater turbine turn and generate electricity.
• In the desert of Oman, a farmer uses seawater to irrigate crops.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Identify evidence that supports and/or does not support the success of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios, societal needs for that resource, and associated environmental risks and benefits.</td></tr>
</table>

3. Describe, select, or identify components of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios supported by given evidence.
4. Evaluate the strengths of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios, societal needs for that resources, and associated environmental risks and benefits.
5. Use an explanation of the design solutions for developing, managing, and utilizing energy and mineral resources to evaluate which design solution has the most preferred cost-benefit ratio.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<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>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create a computational model or simulation of a phenomenon, designed device, process, or system.</td><td>ESS3.C: Human Impacts of Earth Systems
• The sustainability of human societies and the biodiversity that supports them require 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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of factors that affect the management of natural resources include the costs of resource extraction and waste management, per-capita consumption, and development of new technologies.
• Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.

Content Limits
• Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Biosphere, geosphere, hydrosphere, renewable, non-renewable, mitigation, economic cost, irreversible, reversible, exponential, logarithmic, basin, ecological, biome, recycle, reuse, mineral, societal, wetland, consumption, per-capita, mining, conservation, extract, agriculture, timber, fertile land, solar radiation, biotic, abiotic, depletion, extinction, manufacturing, technology</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-3:
• The number of birds and other wildlife in an area decreases by 30% after a shopping mall is built in northern California.
• Two 1,330 square-foot homes are side by side in northern California. One has six solar panels on the roof, and the other does not. During one month in June, the one with solar panels produces less carbon dioxide than the other house by174 kilograms.
• Beetles are present throughout a forest. Chemicals are sprayed at intervals needed to control the beetles on one acre. Fifty years later, this acre is the only part of the forest that has oak trees.
• Three species of fish, the Colorado squawfish, the roundtail chub, and the bonytail chub became extinct in the years immediately following construction of the Glen Canyon Dam in Colorado.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
</table>

1. Use data to calculate or estimate the effect of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.
2. Illustrate, graph, or identify features or data that can be used to determine the effects of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.
3. Estimate or infer the effects of an action or solution that affects natural resources, the sustainability of human populations, and/or biodiversity.
4. Compile the data needed for an inference about the impacts of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity. This can include sorting out the relevant data from the given information (or choosing relevant inputs for a simulation).
5. Using given information, select or identify the criteria against which the solution should be judged.
6. Using a simulator, test a proposed action or solution and evaluate the outcomes; may include proposing modifications to the action or solution.*****
7. Evaluate and/or critique models, simulations, or predictions in terms of identifiable limitations and whether or not they yield realistic results.

*In order to satisfy this PE, the student must use a simulator. Therefore, this task demand must always be used.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-4
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• 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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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>Science Vocabulary Students are Expected to Know</td><td colspan="3">Renewable, non-renewable, mitigation, economic cost, irreversible, reversible, exponential, logarithmic, basin, recycle, reuse, societal, wetland, metal, consumption, per-capita, biodiversity, stabilize, mining, conservation, extract, agriculture, timber, fertile land, solar radiation, biotic, abiotic, depletion, extinction, economics, manufacturing, technology</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-4:
• Recycling and composting almost 87 million tons of municipal solid waste saved more than 1.1 quadrillion Btu of energy; roughly equivalent to the same amount of energy consumed by 10 million U.S. households in a year.
• Mixed Paper recycling saves the equivalent of 165 gallons of gasoline.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Identify evidence that supports and/or does not support the success of the technological solution that reduced impacts of human activities on natural systems.</td></tr>
</table>

3. Describe, select, or identify components of the impacts of human activities on natural systems supported by given evidence.
4. Use an explanation of the impacts of human activities on natural systems to explain the technological solution.
5. Identify or select the information needed to support an explanation of the impacts of human activities on natural systems.
6. Using given information about the effects of human activities on natural systems, select or identify criteria against which the solution should be judged.
7. Using given information about the effects of human activities on natural systems, select or identify constraints that the solution must meet.
8. Evaluate the criteria and constraints, along with trade-offs, for a proposed or given solution to resolve or improve the impact of human activities on natural systems.
9. Using given data, propose a potential solution to resolve or improve the impact of human activities on natural systems.
10. Using a simulator, test a proposed solution to resolve or improve the impact of human activities on natural systems, biodiversity and evaluate the outcomes.
11. Evaluate and/or revise a solution to resolve or improve the impact of human activities on natural systems, and evaluate the outcomes

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS-3-5
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 on Earth’s systems.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using computational models in order to make valid and reliable scientific claims.</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>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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 sea level, glacial ice volumes, or atmosphere and ocean composition).

Content Limits
• Assessment is limited to one example of a climate change and its associated impacts.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Orientation, probabilistic, redistribute, volcanic ash, concentration, electromagnetic radiation, radiation, sea level, geochemical reaction, geoscience, greenhouse gas, atmospheric change, biosphere, global temperature, ice core, methane, glacier</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Anthropogenic, absorption spectrum, determinant, NOX, Carbon Footprint,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-5:
• The model predictions for the Great Lakes region of the United States consist of increased precipitation of 5-30% during the spring and decreased precipitation of 5-10% in the summer.
• Concentrations of CO_2 under the higher emissions scenario for 2100 could reach as high as 850 parts per million (ppm).
• Global warming of 2°C is predicted by the year 2050
• The model mean global temperature change for a high emissions scenario is 4-6°</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in global or regional climate models and their associated future impacts on Earth’s systems.</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in global or regional climate models to forecast regional climate change and the associated future impacts on Earth’s systems. This may include sorting out distractors.</td></tr>
<tr><td colspan="4">3. Use relationships identified in the data to forecast the current rate of global or regional climate change and how it will affect Earth’s systems.</td></tr>
</table>

4. Identify patterns or evidence in the data that supports inferences about how the changing of global or regional climates will affect Earth's systems in the long term.

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<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS-3-6
Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.</td><td>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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include running computational representations but is limited to using the published results of scientific computational models.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Orientation, probabilistic, redistribute, volcanic ash, concentration, electromagnetic radiation, radiation, sea level, geochemical reaction, geoscience, greenhouse gas, atmospheric change, biosphere, global temperature, ice core, methane, glacier</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Anthropogenic, absorption spectrum, determinant, NOX, Carbon Footprint,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-6:
• Beetles are present throughout a forest. Chemicals are sprayed at intervals needed to control the beetles on one acre. Fifty years later, this acre is the only part of the forest that has oak trees.
• In July 2016, the size of the hypoxic area due to algae blooms in the Chesapeake Bay in late June was the second smallest since 1985.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Use data to calculate or estimate the effect of human activity on Earth systems.
2. Illustrate, graph, or identify features or data that can be used to determine the relationships among Earth systems and how human activity is affecting those relationships.
3. Estimate or infer the effects of human activity on Earth systems.
4. Compile the data needed for an inference about the impacts of human activity on Earth systems. This can include sorting out the relevant data from the given information (or choosing relevant inputs for a simulation).
5. Using a simulator, test a prediction and evaluate the outcomes. This may include proposing modifications to the action to mitigate or the solution to the effect(s) of human activity on Earth systems.
6. Evaluate and/or critique models, simulations, or predictions in terms of identifiable limitations and whether or not they yield realistic results.

Appendix 2-C

Style Guide for Science Items

Cambium Assessment
(formerly AIR Assessment)

Three-Dimensional Science Assessment Style Guide

Modified from the Smarter Balanced Style Guide

3-11-2022

Note: The presentation of the sample items and selections in this document approximates but does not exactly reflect the appearance of the test content that students will view on the computer screen. The final presentation of content will depend on the user interface (UI) of the online delivery system.

Table 1. Abbreviations used in Style Guide

Style Guide Abbreviations	
Abbreviation	Spelled-Out Term
CBT	computer-based testing
CMOS	*Chicago Manual of Style*
CMYK	cyan-magenta-yellow-black (a four-color model used in printing)
CR item	constructed-response item
Dpi	dots per inch
JPEG	Joint Photographic Experts Group (a format for compressing images used for print or screen
PBT	print-based testing
PNG	portable network graphics (a format using lossless compression for images used for screen presentation)
RGB	red-green-blue (a three-color model used in screen presentation)
SR item	selected-response item
TEI	technology-enhanced item
TIFF	tagged image file format (a format for compressing images used for print presentation)
UI	user interface

Table of Contents

Part I: Global Style Conventions

A. Computer-Based Testing

Computer-based testing (CBT) differs from traditional print-based testing (PBT). Traditional style conventions applied to printed test forms must be modified for computer-based test forms because not all print-based style conventions are appropriate for display on a computer screen.

For example, the Verdana font has been chosen because it was specifically designed to be used in place of Times New Roman and other serif fonts that often appear in printed test forms. Verdana characters are slightly larger than characters in other fonts, and the ample space between the characters makes them easy to distinguish at low screen resolutions.

Layout Considerations

The presentation of content in computer-based test forms depends on the user interface (UI) in the online delivery system. The guidelines in this section should be applied to the extent possible once the online delivery system is identified.

Content panes

Students should have the option of viewing content in one pane that is the full size of the computer screen or in sub-panes that divide the screen horizontally or vertically. For example, students should be able to view a selection on the screen by itself or on the screen with an item.

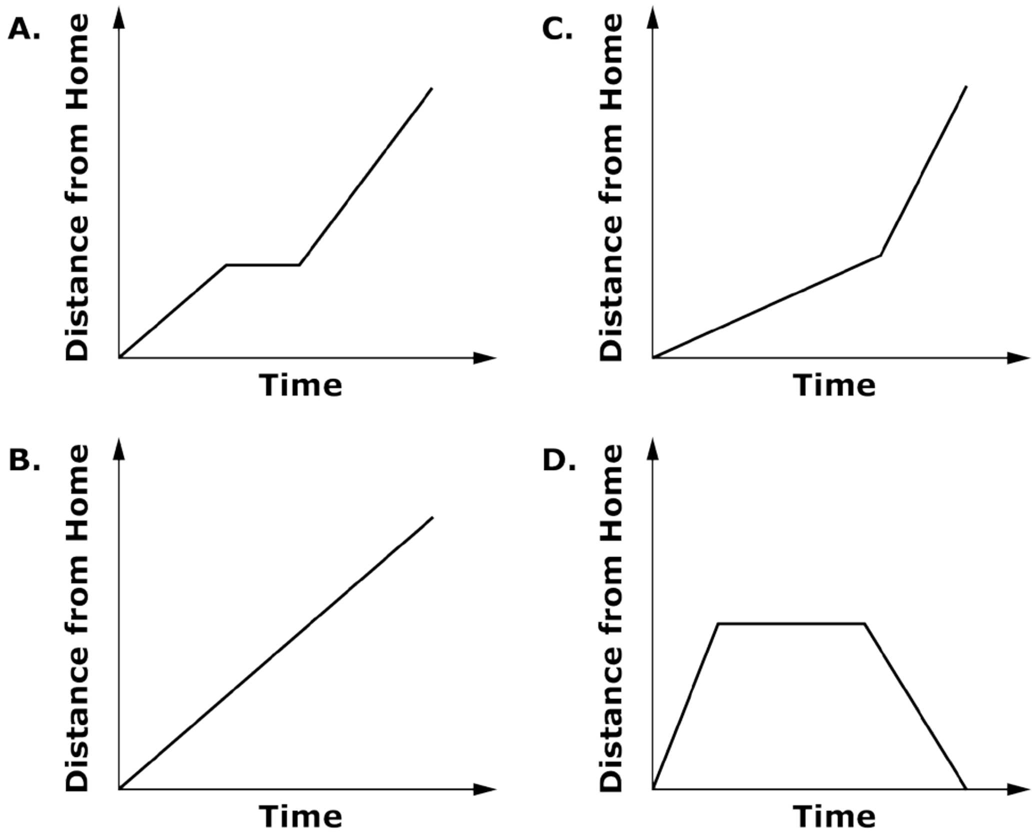
The sizes of content panes depend on the amount of space allotted in the UI for viewing content. For example, content panes will be larger in a UI in which 80% of the viewing area is used for content and 20% is reserved for headers, navigation tools, and other non-content elements than in a UI in which 70% of the viewing area is used for content and 30% is reserved for non-content elements.

Scrolling

Students should not have to use horizontal scrolling to view test content in its entirety. The following guidelines are designed to minimize the need for scrolling:

- Lay out content across the computer screen rather than in columns.
- Display each item on the screen by itself.
- Allow students to view a selection on the screen by itself or on the screen with an item. This eliminates the electronic equivalent of turning a page to flip between the selection and the items.
- Similar options should be provided for viewing a cluster. Students should be able to view the graphic on the screen by itself or on the screen with an item in the cluster.
- Whenever possible, arrange graphic options in a two-over-two box (stacked) layout.

Which graph shows that Noel walked home from school at a constant rate?



Line Breaks
The locations of line breaks depend on the operating system on the computer as well as the size of the monitor being used to view test content. Hard line breaks should not be inserted unless absolutely necessary because lines of text do not necessarily break at the same locations from computer to computer.

B. General Font and Alignment Specifications

Table 2 shows general font and alignment specifications for different text elements. See "Selected-Response Items" in this section for information about option alignment.

Note: All text should be displayed on a white background.

Table 2. General font and alignment specifications for text elements in test forms

Content	Font	Alignment
Items	14 pt. Verdana	Left aligned
Part headings in items	14 pt. Verdana Bold	Left aligned
Boxed text	14 pt. Verdana	• Box: left aligned • Text: longest line centered in box; other lines left aligned on longest line.
Emphasis terms	14 pt. Verdana Bold	n/a

Note: At this time, Verdana is specified as the primary font for test content. However, another font may be chosen upon further analysis of the effects that fonts have on readability and students' ability to retain information.

C. Stimulus Specifications

The stimulus of a cluster describes a scientific phenomenon and provides the student with the necessary context around that phenomenon to answer the associated items. A stimulus may include a title, but a title is not necessary.

Phenomenon
The phenomenon is a scientific observation or an engineering problem around which the cluster is based. The phenomenon should be stated as the first sentence(s) of the stimulus, followed by two hard returns.

Example phenomenon:

> Fog appears and disappears over the course of a morning in the Willamette Valley in Oregon.

Task Statement
The task statement concludes the stimulus by telling the student exactly what he or she is expected to do in the cluster. The task statement is preceded with "Your Task" in bold, followed by two hard returns.

Example task statement:

> **Your Task**
>
> In the questions that follow, you will develop an explanation for the appearance and disappearance of fog.

Note: A standalone item with a stimulus does not have a task statement ("Your Task").

Stimulus Layout
If the stimulus contains information that students will consistently reference when working through the items in the cluster, the writer should select a split-screen layout that allows the stimulus to appear on the left and the items on the right. If the stimulus only serves as an introduction to the phenomenon, the writer should select a single screen layout. Animations, graphics, and other stimulus material should be sized to avoid the need for horizontal scrolling. If it becomes difficult to limit the size of an animation or another element of the stimulus, a single screen layout may be selected to avoid horizontal scrolling.

Wording should be consistent throughout the stimulus and cluster. For example, do not use "steam" and "vapor" interchangeably.

D. Interaction Types

Science assessments consist of various types of interactions, including selected-response (SR) items, constructed-response (CR) items, and technology-enhanced items (TEIs). In test forms, items are numbered sequentially, beginning with number 1.

This section provides general global style conventions and specifications for items. See Part II for content specific conventions and for information about TEIs.

Selected Response Interactions

All SR interactions consist of a stem and options. The format of the stem and options varies among items based on content. (See "Options" in this section for formats of options.)

Stems:

- Stem: the part of the SR item that precedes the options
- Closed stem: a stem that is a complete sentence and ends with a period or question mark
- Open stem: a stem that consists of a sentence fragment and becomes a complete sentence when combined with each option.

Closed stems

When the interaction stem is closed, the options are either complete sentences or sentence fragments. Options that are complete sentences begin with a capital letter and end with a punctuation mark.

How would a fish population affect the stream ecosystem?
A. Fish would lower the water temperature.
B. Fish would produce oxygen from the water.
C. Fish would block sunlight, increasing plant growth.
D. Fish would produce waste, providing nutrients to plants.

Options that are fragments begin with a lowercase letter (unless the first word is a proper noun or adjective) and do not end with a punctuation mark.

The traits of populations in the forest ecosystem have changed over time. What caused the traits to change?
A. natural selection
B. lack of mutations
C. unlimited resources
D. asexual reproduction

The treatment of options that are imperative sentences depends on whether the implied subject of the sentence in each option is "you." If it is, the options are treated as complete sentences. If it is not, the options are treated as fragments.

Subject is implied "you":
What should you do next in the experiment?

A. Water the plants.
B. Label the volumes.
C. Cut the plant stems.
D. Record plant heights.

Subject is not implied "you":
What should Fiona do next in the experiment?

A. water the plants
B. label the volumes
C. cut the plant stems
D. record plant heights

Open Stems
When the item stem is open, both the stem and the options are fragments that, when combined, form complete sentences. The fragment in the stem does not end with a punctuation mark. Regardless of whether the options are complete sentences or fragments, they begin with a lowercase letter (unless the first word is a proper noun or adjective) and end with a punctuation mark.

The independent variable of the investigation is
A. volume.
B. height.
C. mass.
D. time.

In open-stem items, the options should not repeat large quantities of text. The stem must be long enough to provide context for the options. There is **no** punctuation at the end of an open stem (i.e., dash or colon).

The tussock moths obtain energy in cellular respiration by
A. taking in water.
B. releasing oxygen.
C. breaking down glucose.
D. inhaling carbon dioxide.

Options
Although all SR items have options, the number and format of these options vary from item to item based on content. The number of correct answers among the options also varies.

- In the case of a multiple choice interaction, options are identified with consecutive uppercase letters.

What is one purpose of ATP molecules in plant and animal cells?
A. to increase the rate of diffusion across cell membranes
B. to decrease the rate of chemical reactions
C. to store energy used for cell processes
D. to pass genetic traits to offspring

- In the case of a multiple select interaction, options are preceded by open boxes, which students can click on to select the correct answers.

Select **all** the cell structures found in animal cells.

- ▫ cell membrane
- ▫ mitochondria
- ▫ chloroplast
- ▫ cell wall
- ▫ nucleus

Option alignment and order

Table 3 provides general guidelines for the alignment and order of options in SR items.

Note: Options derived from a stimulus, such as a selection or graphic, are ALWAYS arranged in the same order in which they appear in the stimulus. This guideline supersedes all other guidelines listed in Table 3.

Table 3. Guidelines for the alignment and order of options in SR items

Option Alignment and Order			
Option Type	**Alignment**	**Order**	**Example**
Graphic options	• Graphic: left aligned • Option letter: top aligned or vertically centered on graphic (use best judgment)	Arranged for best visual presentation (use best judgment)	n/a
Numeric options	Decimal aligned: • stand-alone numbers • decimal values • numbers that precede or follow symbols: 40°, $20.00 • numbers that precede labels: 6 ties, 12 bananas • numbers that precede units of measure: 15 kilograms, 30 cm	Arranged in ascending or descending order	What percentage of students prefer strawberry yogurt to blueberry yogurt? A. 25% B. 50% How long, in centimeters, is each necklace? A. 9 cm B. 12 cm
	Fractions: • Fraction: left aligned • Option letter: vertically centered on fraction	Arranged in ascending or descending order	How many cups of sugar does the student need to make two cakes? A. 1/2 B. 1/4
	Times of day: • Decimal aligned on colon	Arranged in ascending or descending order	At what time does the student eat lunch? A. 11:30 a.m. B. 1:00 p.m.

Table 3. Guidelines for the alignment and order of options in SR items *(cont.)*

Option Type	Alignment	Order	Example
Text options	Left aligned	Words: arranged in ascending or descending order by word length	What large molecule is made of many small amino acid molecules? A. lipid B. protein C. carbohydrate
	Left aligned	Phrases and sentences: arranged by length, longest to shortest or vice versa; if more than one line of text is used as separate paragraphs (such as a title followed by a description), the length of the first line of text is considered (e.g., the title)	Which statement describes DNA? A. It is a macromolecule. B. It is found in the nucleus. C. It makes up chromosomes.

Note: Options are not arranged in the prescribed order when doing so cues the answer to the item.

Constructed-Response Interactions

CR items consist only of item stems. The stems are complete sentences written as imperative commands.

Explain how the amount of sunlight affects the growth of plants.
Use information from Investigation 1 to support your answer.

Describe how meteorologists predict the weather.
Use information from the Weather Patterns map in your description.

Bullets in Items

- Bullets are used for student action items—what a student must do to earn points, as listed in the rubric.
- Do not use a bullet if there is only one directive in an item.
- Always use bullets to denote multiple directives.

Parts in Items
Some items are divided into parts labeled with consecutive lettered headings that are followed by two hard returns. In headings, the word *part* and the part letter are capitalized and bold. In item text, the word *part* is lowercase and the part letter is capitalized. Parts may comprise a mix of interaction types or multiple interactions of the same interaction type.

Part A

Select a testable, scientific question that can be answered by performing an experiment with the setup shown in the Hanging Magnets Experiment picture.

Ⓐ How does the distance between the magnets affect the force?

Ⓑ How does the orientation of the magnets affect the force?

Ⓒ Will the force between the magnets always exist?

Part B

Use the table to select the properties you want to hold constant and the properties you want to change when you run your experiment to answer the question you chose in part A.

E. Graphics in Items

Introductory Statements

Descriptive terms
A graphic in an item should not be referred to as a *graphic*; instead, use a more descriptive term, such as *graph, table, or diagram*. The graph, table, or diagram should be labeled with a Figure or Table number. Any references in the stimulus or items should use this label rather than the title.

Figure 1. Bird's Nest in Tree
Use Figure 1 to describe …

Table 1. Population of Zebra in the Serengeti
Use Table 1 to predict …

Above and below
Do not use the terms *above* and *below* to refer to the location of a graphic; instead, use terms such as *this, that, an,* and *the*.

An equation is shown.

$$\square + 12 = 42$$

Select the variables that make the equation true.

Introductory statements in the item stems
Graphics positioned within items are aligned to the **center** and introduced as part of the item stem using the Figure or Table number.

Figure 1 shows a diagram of photosynthesis.
Table 1 shows characteristics of two populations of coyote.

An introductory statement that is part of an item stem should be as descriptive as possible; however, a sentence such as "See Figure 3" is acceptable when a more descriptive introduction is not available or appropriate.

Acceptable:
See Figure 3.

Preferred:
Figure 3 shows food relationships among some organisms in the forest ecosystem.

Note: In SR items, stem text will be used before the graphic to introduce the item. The graphic will appear next. The graphic will be followed by any remaining stem text, including the question part of the stem. The options will appear last.

Referring to Text from Graphics in Items

Items sometimes refer to table column headings, labels, and other text in graphics. Use the guidelines that follow to determine the appropriate treatment of text from graphics that is referred to in items. Note that these guidelines apply only to the treatment of graphic text in items, not to the text in the graphic itself. (See Part III for information about the treatment of text in graphics.)

- Text from graphics is not enclosed in quotation marks.
- Titles and headings appear in regular type and follow the same capitalization used in the graphic.

Which unit should be used for the measurements in the column titled Volume of Water?

- Labels and other text appear in regular type but do not necessarily follow the same capitalization used in the graphic. Use the guidelines that follow to determine whether to capitalize labels and other text from graphics.
- Capitalize labels that precede letters or numbers if the label is capitalized in the graphic.

Data from the experiment are shown.

Trial	Speed (m/s)
1	10
2	15
3	25
4	20

Why did Trial 1 have an outcome that was different from the outcome in Trial 3?

- Capitalize labels that are proper nouns.
- Lowercase labels that are common nouns.

Jesse walks three dogs in his neighborhood. Chart 1 shows the number of times he walked each dog last week.

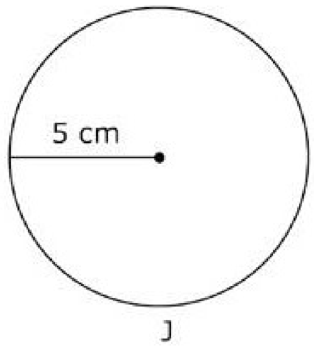
Chart 1

Dog	Number of Times Walked
Schnauzer	5
Beagle	4
Labrador retriever	10

How many more times did Jesse walk the Labrador retriever than he walked the schnauzer?

- Elements are not capitalized when written out (i.e. hydrogen, oxygen)
- Lowercase labels that are lowercase or not shown in the graphic.

The radius of circle J is 5 centimeters.



The radius of circle K is twice as long as the radius of circle J. What is the **diameter**, in centimeters, of circle K?

F. Excerpts and Citations

Excerpts and citations for external sources should be formatted as shown below. Use quotation marks for titles of articles; italicize titles of longer works such as periodicals, journals, and books; and underline web addresses, but make sure there is no live link.

Source 1: Excerpt from "Light as a Broad-Spectrum Antimicrobial" by Peter Gwynne and Maurice Gallagher. Published in the academic journal *Frontiers in Microbiology*, 2018 (adapted from original).

> Research exists regarding the use of light as a sterilizing agent in food and water processing, much of it based around UV light. UV, however, penetrates poorly, limiting its application to surface decolonization. Although UV light is powerful, visible light wavelengths may be better in application.

Source 2: Excerpt from "Ultraviolet Disinfection of Drinking Water" by the Government of Western Australia Department of Heath. Published on the website https://ww2.health.wa.gov.au, 2016 (adapted from original).

> UV light will only travel in a straight line, so any obstruction will reduce its efficiency. Water that has not been filtered can contain iron, manganese, and other particles that can either absorb or scatter UV light, reducing the effectiveness of the system. Bacteria that are able to pass through—protected by shadows created by dirt, debris, or other particles—may be able to survive treatment.

G. Scoring Assertion Specifications

Item writers create scoring assertions to outline the criteria used to score the item. Scoring assertions should capture the features of the student response that receive credit *and* the inference that the test developer would like to make from that evidence. The example below shows several scoring assertions for a multi-interaction item. For each assertion, the test developer describes the features of the student response that receive credit ("The student [selected, identified, etc.] …), then links that feature to an inference about student understanding ("providing evidence of [the ability to, an understanding of, etc.] ….").

Score Rationale	
The student identified distance as affecting the force, providing evidence of the ability to form a conclusion based on experiment data.	✓
The student ran three trials keeping the weight of the box the same, providing evidence of an understanding of how to control variables in an investigation.	✓

Each cluster must have the **minimum** number of assertions when it goes into the Locked Operational Pool. To accomplish this, clusters should be created and revised to have at least two more assertions than the minimum to account for interactions and assertions being changed, collapsed, or rejected throughout the review process.

- **Minimum** number of assertions for final operational version of a cluster:
  - Elementary: 5
  - Middle: 7
  - High: 7

- **Recommended minimum** number of assertions for working drafts/versions of a cluster:
  - Elementary: 7
  - Middle: 9
  - High: 9

H. Exemplar Conventions

When to Create Exemplars

There are three main reasons to create exemplars.

1. There must be an exemplar created for each point value before an item can be web approved.
    a. Considering that clusters can have a larger number of possible point combinations, we propose that each exemplar created after the first exemplar adds the next consecutive assertion. See example below.
2. There should be an exemplar for each dependent scoring possibility, or one example in the case of infinite possibilities.
    a. The dependent assertion exemplar should highlight the specific dependency. We recommend that each exemplar have the minimum number of assertions marked as true (only respond to the parts relevant to the dependency), so that it is easier to highlight the specific assertions and interactions involved in the dependency. This will likely mean that most dependency exemplars will be 1 point.
3. Exemplars can be created to highlight responses that are not scoring properly.
    a. The reviewer should leave a comment in ITS that explains why the exemplar was created.

       "The dependent scoring in part B does not work as described in the assertion text. See CR1Review_PartB for the response that should receive credit but does not."

    b. The exemplar should be deleted when the issue is resolved.

Naming Conventions

Each exemplar should begin with a tag that indicates what type of exemplar it is, followed by a short description.

- Standard
    - This denotes "normal" scoring.
    - Follow with the point value:
        - Standard_2pt
        - Standard_FullCredit
- Dependency
    - This denotes that the exemplar relates to dependent scoring.
    - Follow with what part or parts are involved in the scoring, as well as a short description if there are several dependencies in those same parts.
        - Dependency_PartAB
        - Dependency_PartABC_greater
        - Dependency_PartA
- Review
    - This denotes a response that a reviewer had specific concerns about.
    - Begin with the review level in which the issue was found.
        - CR1Review_1pt
        - CR1Review_PartABC_greater

Example from Staging Site – IAT Sandbox 18402

Name	Points	Actions
Standard_FullCredit	3	View Delete
Standard_2pt	2	View Delete
Standard_1pt	1	View Delete
Dependency_PartAB	1	View Delete
Dependency_PartABC_greater	1	View Delete
Dependency_PartABC_equal	1	View Delete
CR1Review_1pt	1	View Delete
No response	0	View Delete

Exemplar: Standard_2pt

Saved By: Matthew_Davis
Date Saved: 4/22/2020 2:04:25 PM
Approved: No

Score response when exemplar was saved:
Your respnse earned **2** points of a possible **3**

Score Rational	
The student entered a value of 5.	✓
The student entered a value of 7 for y, or a value that corresponds to the value of x entered in part A.	✓
The student selected x < y or a selection corresponding to their values in parts A and B.	✗

I. Option Rationales (Formative, specific projects only)

IAT Options

- Multiple Choice: Select only one option.
- Multiple Select: Select two or more options.

Formatting Rationales

- Rationales for correct answers start with: "Key - …"
- All rationales provide a brief reasoning for why the response is a key or distractor relative to the prompt.

Multiple Choice Example

How does energy flow through the ecosystem?

A. The algae produce their own food.
Key - The algae are producers and, therefore, make their own food.

B. The salmon makes its own energy.
The salmon is a consumer and must get its energy from eating other organisms.

C. The sculpin relies on the salmon for energy.
The sculpin is eaten by the salmon.

D. The mollusk produces energy from the salmon.
The mollusk is not eaten by the salmon.

Multiple Select Example

Select the **three** fossils of organisms that lived more than 300 mya (million years ago).

□ Fossil 1
This fossil is found in the rock layer at the top of the column, which means the organism lived less than 30 mya.

□ Fossil 2
Key - This fossil is found in the second rock layer from the bottom of the column, which means that the organism lived 450–500 mya.

□ Fossil 3
Key - This fossil is found in the bottom rock layer of the column, which means the organism lived over 550 mya.

□ Fossil 4
This fossil is found in the second rock layer from the top of the column, which means the organism lived less than 100 mya.

□ Fossil 5
Key - This fossil is found in the bottom of the rock layer of the column, which means the organism lived over 550 mya.

J. Paper Style

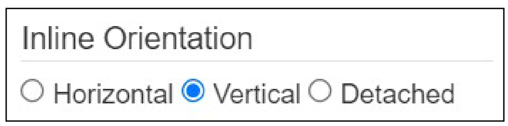
Compatible Item Types

ETC, MC, MS, Table Match, EQ

In most cases, language should be edited as little as possible to make the directions appropriate for paper use. However, the goal for the students is to make the testing experience as similar to the online experience as possible, so in some cases, the addition of directions is recommended in order to clarify instructions for interactions that are clearer online.

ETC Interactions

- Instead of "Click on the blank boxes to select …" stems should read "Select the word or phrase …" or "Select a word or phrase …."
    - If there are multiple ETCs in one interaction, use "Select a word or phrase in each box to …" or similar. It needs to be clear that only one selection in each grouping should be made. In causal chains especially (depending on the style), it needs to be clear that only one statement should be selected for each step. In these cases, "in each box" should be included in the stem for clarity.
    - In the ETC interaction, change the options to orient vertically. They should appear vertically in a box rather than next to each other horizontally.



- For ranking interactions, use "Fill in the bubbles to rank …."
- For interactions in which it is not obvious that students should make only one selection for each step—such as flowcharts or tables—add the statement "Make only one selection for each step." "Step" may be replaced with an appropriate term for the interaction.
    - This statement is added because online, once students make a selection, that is the only selection shown, so they cannot accidentally select another choice. On paper, students may accidentally fill in multiple bubbles in the same step. The addition of this wording reduces the likelihood that students would make this mistake, therefore making the experience closer to the online testing experience.

MC and MS Interactions

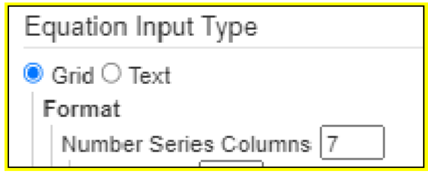
- Wording should match online wording.
- For choice interactions with graphics as options that are all vertical, consider changing the options to 2x2 (two rows with two options each).

Table Match Interactions

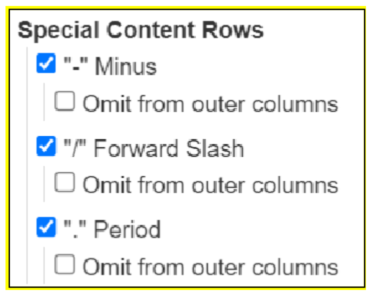
- Wording should be changed to "Fill in the bubbles to select/identify/etc. …."
- If the online version of a table match allows only one box to be checked per row or column and this would not be obvious to the student viewing the item on paper, add verbiage to make this clearer, e.g., "Fill in one bubble in each row."

Equation Interactions

- Check that the stem makes sense, given the appearance of the EQ on paper, and edit if needed. Include "Enter a number in each blank box." In the EQ Paper Renderer, always include 7 digits (columns), for **all** grade levels. This is consistent with the Math team's paper style.



- Make the bubbles match what is available in the online rendering as much as possible. That is, if subtraction, decimal, and/or fraction/division is allowed in the online version, include these for paper as well (note, however, that multiplication and addition are not available for paper). If they are not allowed for online, do not include them for paper. Machine scoring for paper works the same way as the scoring in the grub, so we can allow students to enter expressions on paper the same way we do for online.



Graphics

All graphics will be converted to grayscale. Ensure that graphics render appropriately. Graphics that require students to differentiate between colors should be avoided when possible. If the item refers to the colors in stems or options, but colors are not labeled in the graphics, labels should be added. Check any color graphics with the monochromacy view on the Coblis website (https://www.color-blindness.com/coblis-color-blindness-simulator/) to see whether edits are needed (e.g., adding patterns if colors appear the same in grayscale).

Example: Figure 1 shows parent flowers and offspring of various colors, and those colors are not labeled in the graphic. The question relating to Figure 1 is written as:

Describe the inheritance pattern of the flowers shown in Figure 1.

A. Yellow flowers inherit their color from their parents.

B. Orange flowers inherit their color from their parents.

C. Blue flowers develop their color based on the environment.

D. White flowers develop their color based on the environment.

Labels should be added to Figure 1 to clarify the color of each flower in the diagram because the colors cannot be determined in grayscale.

K. Preferred Editorial Styles

Spelling and Plurals

Common nouns
The plurals of most nouns are formed by adding *s*: boys, trees. Exceptions to this rule include the following:

- The plurals of words that end in ch, j, s, sh, ss, x, or z are formed by adding *es*: churches, biases, wishes, classes, foxes, waltzes.
- The plurals of words that end in a consonant and y are formed by changing *y* to *i* and adding *es*: babies, realities.
- The plurals of words that end in o are formed by adding es or s: heroes, potatoes, egos, cellos.
- The plurals of words that end in f or fe are usually formed by changing *f* to *v* and adding *es*: hooves, lives, but dwarfs, roofs.

Note: Many nouns have irregular plural forms (child/children, deer/deer, die/dice). When in doubt about the form or spelling of a plural, consult a dictionary.

Compound nouns
The plural of a hyphenated compound noun is usually formed by adding s to the main noun in the compound: brothers-in-law, courts-martial.

For solid, or closed, compound nouns, plurals are formed the regular way: classrooms, cupfuls, stopwatches.

The plurals of open compound nouns are formed by pluralizing the main noun: attorneys general, centers of industry.

Proper nouns
The plurals of proper nouns are usually formed by adding *s* or *es*. The plural of a proper noun ending in *y* takes an *s* (Monday/Mondays, the Smith family/the Smiths).

Letters, numbers, and abbreviations
The plurals of capital letters used as words, numerals used as nouns, and abbreviations are usually formed by adding *s*. To avoid confusion, the plurals of lowercase letters are formed by adding an apostrophe and an *s*.

Juan received all Bs on his report card.
the 1880s
DVDs
x’s and *y*’s

Possessives

Singular nouns
The possessive of most singular nouns, both common and proper, is formed by adding an apostrophe and an *s*. This includes words that end with an unpronounced *s* and names with an ending pronounced *eez*.

the marquis’s quarters
Albert Camus’s novels
Euripides’s works

However, a noun that is singular in meaning but plural in form takes an apostrophe only.

this species' characteristics
Hocking Hills' nicest campground

Plural nouns
The possessive of most plural nouns is formed by adding an apostrophe only.

the Joneses' house
the Martinezes' son
but
children's literature
women's rights

Letters and numbers
The possessive of letters and numbers is formed by adding an apostrophe and an *s*.

LBJ's diary
1980's worst flood

Joint vs. separated possession
When closely linked nouns are considered a single unit and "possess" the same thing, only the second noun takes an apostrophe and an *s*.

my mom and dad's house
Amelia and Brianne's teacher

When the things being possessed are not the same, both nouns take an apostrophe and an *s*.

my mom's and dad's birth certificates
Cleveland's and Chicago's rail systems

Compound Terms

compound noun: two or more nouns combined to form a single noun
compound modifier: a modifier that consists of two or more words

- An *open compound* is written as two words: real estate, sand dollar.
- In a *hyphenated compound*, the words are joined by a hyphen: self-esteem, half-baked.
- A *solid compound* is written as one word: playground, textbook.
- Avoid compound modifiers like "fish-eating bird." Instead use "a bird that eats fish."

Compound modifiers
Compound modifiers are usually hyphenated before a noun and open after a noun.

an open-ended question; a question that is open ended
a well-read student; a student who is well read
a 250-page book; a book that is 250 pages long
a sixteen-ounce bottle; a bottle that holds sixteen ounces

There are a few exceptions to this rule:

- When the compound modifier is a common open compound noun, it should be hyphenated only to prevent ambiguity.

  high school teacher
  real estate listing
  but
  short-story writer
  real-number theory

- When the first modifier in the compound is an adverb that ends with –*ly*, the compound is open.

  highly paid assistant
  hotly contested campaign

- When the compound is made up of a number and an abbreviated unit of measurement, the compound is open.

  a 5 km race
  a 3 m wall

- When a phrase is used as a modifier, it is usually hyphenated before a noun and open after a noun.

  over-the-counter medicine; medicine sold over the counter
  an up-to-date form; a form that is up to date

- When the second part of a compound modifier is omitted, a space follows the hyphen.

  fifteen- and twenty-year mortgages
  micro- and macro-evolution
  but
  third-, fourth-, and fifth-grade students

Prefixes and suffixes
Words that are formed with common prefixes and suffixes (*anti-, bi-, mid-, multi-, non-, over-, post-, pre-, re-, sub-, un-, under-, -fold, -less, and -like*) are usually closed.

Bivalve
Catlike
Multipurpose
Noninvasive

However, a hyphen should be used

- before a numeral or a capitalized word: post-1800, mid-September.
- before a compound term: non-self-sufficient.
- to separate combinations of letters that might be hard to read: anti-intellectual, de-ice, lava-like.

Use an en dash instead of a hyphen in a compound adjective when one of its elements consists of an open compound: post–World War II.

Capitalization
Proper nouns and adjectives are always capitalized.

Personal names and titles
All personal names (first, middle, last) are capitalized, as are initials, nicknames, and the suffixes Jr. and Sr. Do not set off a suffix with commas. Include a space between the initials in a personal name except when the initials are used alone.

Susan B. Anthony
Ivan the Terrible
E. B. White
Martin Luther King Jr.
LBJ

A person's title or office is capitalized only when it directly precedes a personal name and is part of the name.

President Lincoln; the president
Professor Johnson; the professor
Reverend Jackson; the reverend
General Grant; the general

When a title is used in apposition to a personal name (meaning it is used as a description rather than as part of the name), it is lowercase.

American president Lincoln
former president Bush
the Southern-born reverend Jackson

Kinship names
Kinship names are lowercase unless they directly precede or replace a personal name. When kinship names are used in apposition to personal names, they are lowercase.

My mom and dad have been married for 30 years.
Did you write to Aunt Kelly?
Can I have a cookie, Mom?
My kids love their aunt Kelly.

Racial and Ethnic names
Names of ethnic and racial groups are capitalized, as are adjectives derived from them. Do not hyphenate compound terms.

African Americans; African American poetry
Asians; Asian influence; an Asian American
Caucasians; Caucasian population

Geographic names
Proper names and nicknames are capitalized.

New York City
the Big Apple

Directional nouns are lowercase when they are used to indicate direction but capitalized when they refer to a distinct region.

a north wind; North African countries; in northern Africa
a southern climate; southern Ohio; the South; South America
eastern Illinois; the East Coast

Trademark and brand names
Use generic terms whenever possible. When using a brand name that is trademarked, capitalize the name but do not include the trademark symbol.

Post-it Notes; sticky notes
Kleenex; tissue

Titles of Works

Capitalization
Use headline style capitalization for titles of works. Capitalize the first and last words of the title and all interior words except

- articles (a, an, the).
- coordinate conjunctions (and, but, for, or, nor).
- prepositions, regardless of length, unless they are functioning as nouns, adjectives, or adverbs.
- the word *as.*
- scientific terms/names that begin with a lowercase letter (pH) or are lowercase in running text (*E. coli*).

Driving through Vermont
"The Ins and Outs of Trail Running"
"Reading for Fun"
Turn Up the Volume
A Primer on Soil pH

Hyphenated compounds in titles
Use the following guidelines for capitalizing a hyphenated compound in a title:

- Capitalize the first element of the hyphenated compound.
- Capitalize any subsequent elements unless they are articles, coordinating conjunctions (and, but, for, or, not), or prepositions.
- If the first element is a prefix or combining form that could not stand by itself as a word (anti, pre), do not capitalize the second element unless it is a proper noun or proper adjective.
- Capitalize the second number in a hyphenated number or fraction that is spelled out.

Heights of Sixth-Grade Students
Teacher-to-Teacher Initiatives
E-learning for Students
The Animals of Sub-Saharan Africa
Twenty-First-Century Skills
The Two-Thirds Majority

Tense
Present tense is the default tense. Some sentences will be in future and past tense.

Treatment of Terms

Note: See "Treatment of Numbers" in Part III for information about the preferred treatment of numbers.

Avoid the use of these words and phrases on science assessments:

- believe
- create
- prove (science does not work to prove hypotheses or theories true—this is a mischaracterization of how science works)
- truth (science is asymptotic to truth)
- above and below (referring to tables or graphics)
- of the following

Emphasis terms
Emphasis terms are boldface at all grade levels.

> Select **all** the questions you could ask to help solve the dilemma.
> Select **two** characteristics that can be hereditary.

However, avoid using qualifying terms like "best," "most likely," etc. In the rare instances when these terms are used, they should be boldface.

> Which is the **most likely** reason the population of deer decreased?

Letters as letters
Letters referred to as letters in text are italicized.

> Liam has 2 plant pots labeled with the letter *E*, 2 plant pots labeled with the letter *F*, and 2 plant pots labeled with the letter *G*.

Contractions
Contractions can be used in selections and other material from outside sources (e.g., stimuli). However, contractions are not used in items.

Options
The term "option" is never used in a prompt.

> Incorrect: "Select the option" or "Which option"
> Correct: "Select the [sentence, element, design, etc.]" or "Which [sentence, element, design, etc.]"

Abbreviations

> Note: Except for abbreviated units of measure and forms of address, abbreviations are rarely used in items. Abbreviations are used in graphics when space is an issue.

Acronyms and initialisms
acronym: an abbreviation based on the initial letters of a term and pronounced as a word (NASA, OPEC)
initialism: an abbreviation based on the initial letters of a term and pronounced by spelling out each letter (AARP, DNA)

Acronyms and initialisms are usually set in all capital letters without periods. When an acronym or initialism is preceded by an indefinite article, the choice of a or an is based on the pronunciation of the abbreviation.

an HMO
an AARP newsletter
a DNA sample
a NASA initiative
an OPEC worker

Unless an acronym or initialism is extremely well known (e.g., IRS, PTA, NATO), spell it out the first time it is used and enclose the abbreviated form in parentheses after the spelled-out term.

The grade-level expectations (GLEs) for science are listed below.
The GLEs for English Language Arts (ELA) are listed in the next section.

Latin abbreviations
Use Latin abbreviations only in parenthetical text. The abbreviations most commonly used are e.g. (for example), etc. (and so on), and i.e. (that is). In text, these abbreviations are set in regular type.

Unapproved resource materials (cell phones, dictionaries, etc.) are not allowed during test sessions. Reference books (i.e., dictionaries, thesauri) are not allowed during test sessions.

Taxonomic/Systematic conventions
Genus and species names should always be written in italics, including where they appear in figures and tables.

Tyrannosaurus
Tyrannosaurus rex
T. rex

Genus and species abbreviations are written in a combination of italicized and non-italicized text.

cf. *Tyrannosaurus*
Tyrannosaurus cf. *rex*
Tyrannosaurus sp.
Tyrannosaurus spp.
Tyrannosaurus insertae sedis

Names for other systematic groups should not be written in italics (e.g., Plantae, Animalia, Abelisauroidea, Dromaeosauridae)

Genotypes
Genotypes and single allele letters should be italicized.*

Gg
BB
dd

*except when text formatting is not available within an interaction type (e.g., ETC dropdown options and table input boxes)

Geographic abbreviations
The names of states are spelled out in running text. Abbreviations are used where a zip code follows or in other contexts in which abbreviations are appropriate (e.g., acknowledgments, graphics, tables, lists). In these cases, use the two-letter postal abbreviations without periods.

Spell out United States when it is used as a noun; either the abbreviation U.S. or US may be used as an adjective.

> The campus is in Westerville, Ohio.
> Please mail the documents to PO Box 121, Cloverdale, VT, 00111.
> the president of the United States (*not* the president of the US)
> the U.S. Treasury Department

Time
Use capital letters without periods in indicate eras. (Note that BC and BCE follow the date, while AD and CE precede the date.)

> 55 BC
> AD 1066

Months are spelled out in running text but may be abbreviated in graphics. Use the following abbreviations:

Jan.	May	Sept.
Feb.	June	Oct.
Mar.	July	Nov.
Apr.	Aug.	Dec.

Days of the week are spelled out in running text but may be abbreviated in graphics. Use the following abbreviations:

Sun.	Thurs.
Mon.	Fri.
Tues.	Sat.
Wed.	

Times of day: Lowercase letters followed by periods are used for a.m. and p.m.

Millions of years ago (or million years ago): mya

> 500 mya
> 1 mya

Part II: Specific Style by Interaction Type

A. Multipart Items

Many items within a cluster will have more than one interaction for the student to complete. The types of interactions can differ throughout the item or the item can consist of one type of interaction repeated.

- Each interaction heading, or "part heading," is title case and **bolded** before the stem of the interaction.
- There should be two hard returns between the part heading and the stem.

Part A

Select a testable, scientific question that can be answered by performing an experiment with the setup shown in Figure 1.

Note: The preamble sentences "The following question has two parts. First, answer part A. Then, answer part B." are no longer used for our science items.

For the stem of subsequent interactions, do not refer back to the student's response to previous interactions ("… you chose in part A") unless there is dependent scoring. This referencing suggests that the student can get credit for pairing parts A and B correctly without selecting the correct answer to the question for part A.

Use:
Which given evidence supports the answer to part A?
OR
Which statement provides a reason for the answer to part A?

B. Multiple Selection (Multi-Select) Interactions

Multi-select items are selected response items that allow the student to choose more than one option.

Note: For multiple choice interactions, see "Selected-Response Interactions" in Part I.

Task Directions

- For all elementary and middle school interactions use "Select (number of options) …" The number should be spelled out and **bolded**.

  Select **four** statements that describe predator-prey relationships.

- For some high school interactions, the exact number of selections may be omitted.

  Select **all** the statements that describe predator-prey relationships.

Options

- If options are one word or phrase, use lowercase; no punctuation is necessary.
- Option order:
  - In the order they appear in a stem graphic or table
  - In ascending order, if numeric options
  - Alphabetically or ascending or descending order, if all options are one word
  - By ascending or descending order, if phrases
  - If graphics only, arrange in a logical order

Human Readable Rubric

The human readable rubric outlines correct responses to the item.

Example:

A full-credit (1 point) response includes
The student selected:

- "the flower is red"

AND

- "the flower is blue"

C. Edit Task Inline Choice (ETC) Interactions

ETC items allow students to select a response from a dropdown menu in order to complete a sentence or a cell in a table.

Task Directions
For one dropdown box, use: "Click on the blank box and select the word/phrase …"
For two or more dropdown boxes, use: "Click on each blank box and select a word/phrase …"
OR
"Click on the first blank box and select the word/phrase …. Then, click on the second blank box and select the word/phrase …."

> Note: When the student is directed to complete a model, causal chain, steps in a process, or similar task, do not use the phrases "in order" or "in sequence" as that is implied in the directive (the student would not be completing a chain of causality if the steps were out of sequence). (But see note in section H, External Copy Interactions.)

Options
The number of options in each dropdown will vary from dropdown to dropdown and from item to item based on content.

Dropdown options that are full sentences should have initial caps and end punctuation. In tables and other graphics, dropdown options that are fragments should have initial caps and no end punctuation.

The options within the dropdowns should be ordered using the same guidelines as multiple choice and multi-select interactions, most commonly in ascending length.

Human Readable Rubric
Example:

> A full-credit (1 point) response includes
> The student selected:
> - "increased" for the first blank
>
> AND
> - "increased" for the second blank
>
> OR
>
> - "decreased" for the first blank
>
> AND
> - "decreased" for the second blank

Exemplar: Include the correctly completed sentence, diagram, or table.

D. Table Interactions

Table Match Interactions

Table match interactions allow the student to select cells within a table to show a relationship between the column header and the row header.

Task Directions

- Use: "Select the boxes to identify each organism's role in the ecosystem." OR "Select the boxes to show the order of the steps of (process) …"
- When there is more than one correct answer combination in an item, the following guideline **may** be included:
    - There may be more than one correct answer.
- When it is unclear that a student can and should select more than one box, the following guideline should be included:
    - You may select more than one box for each part …

Tables

- Column and row headings may contain text or graphics. When graphics are present, it is preferable for a text label or descriptor to be present.
- In the directions, refer to the first column first (when possible).
- If the text in the column or row heading is a complete sentence, it should begin with a capital letter and end with the proper punctuation.
- If a column or row heading is a phrase or one word, it should begin with a capital letter and should not have punctuation.
    - The subsequent words of a phrase should not be capitalized, unless the phrase is a proper noun or adjective.
- Within an item, column headings must all follow either title case/capitalization or sentence case. Within an item, row headings must all follow either title case/capitalization or sentence case.
- Title and sentence case/capitalization should be used consistently. Column and row headings should be in one of the following orders when they appear:
    - In the order they appear in a stem graphic or stem table
    - In ascending or descending order if all options are one word
    - By length (ascending/descending), if phrases
    - If graphics only, arrange in logical order
- Column headings should be bolded, centered, and boxed and have no shading.
- Row headings should be normal weight text and have no shading.
    - Left align row headings when one or more headings have more than one word
    - Center row headings that are a single word or number

Human Readable Rubric

- Use quotes to reference the row and column headings in the interaction.
- Row and column heading references are capitalized as they are in the interaction.
    - o Row and column headings with no text should be described. Example: the picture of a new moon
- Example:

  A full-credit (1 point) response includes
  The student selected:
    - o "Blue" and "Green" for "Reflected"

  AND
    - o "Orange" and "Yellow" for "Absorbed"

  AND
    - Nothing else

Exemplar: Include a correctly completed table.

Table Input Interaction
Table input interactions allow the student to enter numbers, symbols, and/or words into the cells of a table.

Task Directions
- Use: "Enter the [number, value, etc.] in the blank box."
- Let the student know if there is more than one correct answer.

Note: For table specifications, see the "Table" section of "Table Match Interaction."

Human Readable Rubric
Example:

> A full-credit (1 point) response includes
> The student entered:
> - "8" for column 2, row 2
>
> AND
> - "12" for column 3 row 3

Exemplar: Include a correctly completed table.

E. Hot Text Interactions

Hot text interactions allow the students to click on text to "select" it.

Task Directions

- Use "Select the [words, sentences, etc.] that …"

Human Readable Rubric
Example:

A full-credit (1 point) response includes
The student selected:
- "nucleus"

AND
- "cell wall"

F. Graphic Response Interactions

Graphic response or "grid" interactions allow students to drag/ drop, draw dots or lines, and/ or use hot spots to complete a diagram or model.

Note: See the "Graphs" section of Part IV for graph specifications.

Task Directions

- Response boxes contained in the grid background are referred to as "blank boxes" in task directions and guidelines.
- References to "correct," "appropriate boxes," etc., in the task directions and guidelines should be avoided.
- To help the student navigate the various components of the item, use consistent language in the stem, palette objects, and answer space.
    - For example, if the item is about Jupiter, the various components of the item should use the word "Jupiter" and not the more general reference to "planet."
    - If the palette objects are referred to as "birds" in the task directions, they should be referred to as "birds" in the guidelines as well.
    - This consistency should be extended to the scoring assertion rationales.
- Whenever possible, refer to the material in the answer space in specific terms ("in the picture," "in the table," "in the graph," etc.). Do not use the terms "graphic," "image," or "answer space."
- References in the stem to diagram headings and grid background titles should be in the same capitalization as in the headings and titles but should not be bolded.
- Whenever possible, refer to the palette objects and groups of palette objects in specific terms (e.g., "chemical elements").
    - Reference to two or more palette objects should be lowercased.
    - If the palette objects are just pictures, lowercase the references to them in the stem.
    - Reference to a specific palette object in the stem should use the same capitalization as in the palette object labels.
- If it is not possible to refer to palette objects in specific terms, then:
    - A palette object that includes a picture, with or without a label, is referred to in the item as an "object/picture/diagram."
    - A palette object that is text only can be referred to as a "label/name."
    - A mixed collection of palette objects can be referred to as "object/label."
    - **Do not** use the term "palette object."
- **Palette Bar Drag and Drop Interactions:** For interactions where palette objects appear in the left palette bar, use the verb and preposition "Place … in …" in task directions. Also, refer to boxes with dashed lines as "blank boxes." (Note: Do not use the term "drag.")
- **Pre-placed Drag and Drop Interactions:** For interactions where palette objects are preset in the gray pre-placed box in the grid background, use the verb and preposition "Move … into …" in task directions. Also, refer to boxes with dashed lines as "blank boxes." (Note: Do not use the term "drag.")
    - Pre-placed interactions should **not** have a Delete tool. The student will not be able to get the palette object back once it is deleted, so the tool is not needed.
- **Hotspot Interactions:** Interactions that allow students to select multiple words, text graphics, etc. on the background in order to complete their machine scored constructed response. For these interactions, use the verb "Select …" in task directions.
- **Hotspot Bar Graph Interactions:** Interactions that allow students to construct a bar graph. For these interactions, use "Click on a line to show where the top of each bar should be" in the task directions.
    - Note: Bar graph interactions should have only 'select' hotspots. Do not add 'hover' hot spots for any grade level. This is consistent with AIR math item development.
- **Graphing Interactions:** Interactions that require the student to use the "Add Point,"

"Connect Line," and/or "Add Arrow" tools. For these interactions, use the verb "Use …" in the task directions; also, use the term "tool," not "button" (e.g., "Use the Add Point tool to …").

   - Note: Interactions that contain the "Connect Line" and/or "Add Arrow" buttons must also have the "Add Point" button. Buttons should be in the following order: Delete, Add Point, Connect Line, Add Arrow (single), Add Arrow (double).

- When applicable, the following guidelines should be included:
   - "Use only **one** [palette object] in each blank box you fill in."
      - Note: this is used in all drag and drop items in which only one answer is required or fits in each blank box. Also, the word "one" should be bolded.
   - "The [palette objects] may be used once, more than once, or not at all."
   - "The [palette objects] may be used more than once."
   - "Not all [palette objects] may be used."
      - Note: this is used when the number of palette objects equals or exceeds the number of blank boxes.
- The guidelines above may vary in language in order to reference specific aspects of an interaction.
   - Use specific references to the object, rather than the word "object," when possible. If not possible, use "object."
   - For items that have only labels and no objects, use "label."
   - For items that have only one box to fill in, use "the blank box."

Human Readable Rubric

- It is not necessary to use quotes for references to palette objects or graphic labels in written rubrics.
- Palette objects with text are capitalized as their labels are capitalized, and are not described as "the 'Maple Tree' object."
- Palette objects or response box locations with no text should be described. Example: "the picture of a new moon."
- Example:

  A full-credit (2 point) response includes
  The student placed:
   - Only the red bird in the smallest birdhouse region

  AND
   - Only the black bird on the power lines OR on the roof

- Exemplar: Include a snapshot of the correct response.

G. Simulation Interactions

Simulation interactions allow the student to investigate a phenomenon by selecting variables to get output data. Some simulations are accompanied by animations.

Task Directions

Simulation directions should be as clear and simple as possible.

- State the task clearly and concisely.
- Use either "controlled experiment" or "investigation" when discussing the type of activity the student is using the simulation for.
- Include the directive to either "Click on Start to [run a trial, see the results, etc.]" or "Click on Run to [run a trial, see the results, etc.]" depending on whether the button says "Start" or "Run."
- State the number of trials that can be run.
- A guideline should always be included informing the student as to whether they can delete trials using the trash can icon or not.
- Provide the student enough direction that they will provide the information needed for scoring.

Examples (prompt only):

> Use the simulation to gather measurements that can be used to predict the weather.
>
> Use the simulation to test prototypes for the design.

Example (prompt with guidelines):

> Use the simulation to conduct a controlled experiment to determine what makes the balloon float.
> - You will be limited to **five** trials.
> - Click on Start to run a trial.
> - Click on the trash can at the end of the row to delete a trial and generate new data.
> - You will be scored only on the trials present in the simulation table.

Layout

Layouts of the simulation will vary due to content being investigated.

Animations

Animations within a simulation should follow the standard animation guidelines. Animations should be as short as possible in order to decrease the amount of time spent on the simulation by the student. Use the directive to "Click on the small gray arrow to start the animation …" OR "Click on the small gray arrow to watch [Earth revolve around the sun, the rabbit come out of its hole, etc.]."

- Animations within a stimulus should be no wider than 350 pixels to avoid horizontal scrolling.

Output Table

Output tables should follow the same format and style of data tables presented in text.

Human Readable Rubric

- Students are scored on their decisions during the investigation.
- The combination of variables needed for each score point should be listed.
- Example:

A full-credit (3 point) response includes

The student ran trials with the following variables:

- "blue," "heavy," and "square"

AND

- "yellow," "heavy," and "square"

AND

- "blue," "light," and "square."

- Exemplar: Include a snapshot of a correct output data table.

H. External Copy Interactions

External copy items allow the student to select text from the stimulus to copy into the answer space.

Task Directions

- Click on the first pencil icon.
- Then, click on a highlighted step [or "section from the passage"*] to make your first selection. Click on the other pencil icon(s) to make your remaining selection(s).
- Click on the circular arrow that follows any selection you would like to change.

**Or "source(s)," "part C," or any other text that will become highlighted by the pencil; do not use "stimulus."*

Note: When the student is directed to complete a model, causal chain, steps in a process, or similar task, and the steps are given in a list, cite in the introduction to the list and in the item prompt that they are out of order and should be placed in order. (But see note in section C, Edit Task Inline Choice [ETC] Interactions.)

Human Readable Rubric

The human readable rubric outlines correct responses to the item.

Example:

A full-credit (1 point) response includes
The student selected:

- "the flower is red"

AND

- "the flower is blue"

E. Equation (EQ) Editor Interactions

Equation (EQ) Editor interactions allow the student to enter numbers, symbols, etc. into the answer space by either typing them manually or by using the built-in keyboard.

Task Directions

- Use “Enter the [equation, number, value, etc.] in the blank box.”

Human Readable Rubric
Example:

A full-credit (1 point) response includes
The student entered the equivalent of:

- “10.512”

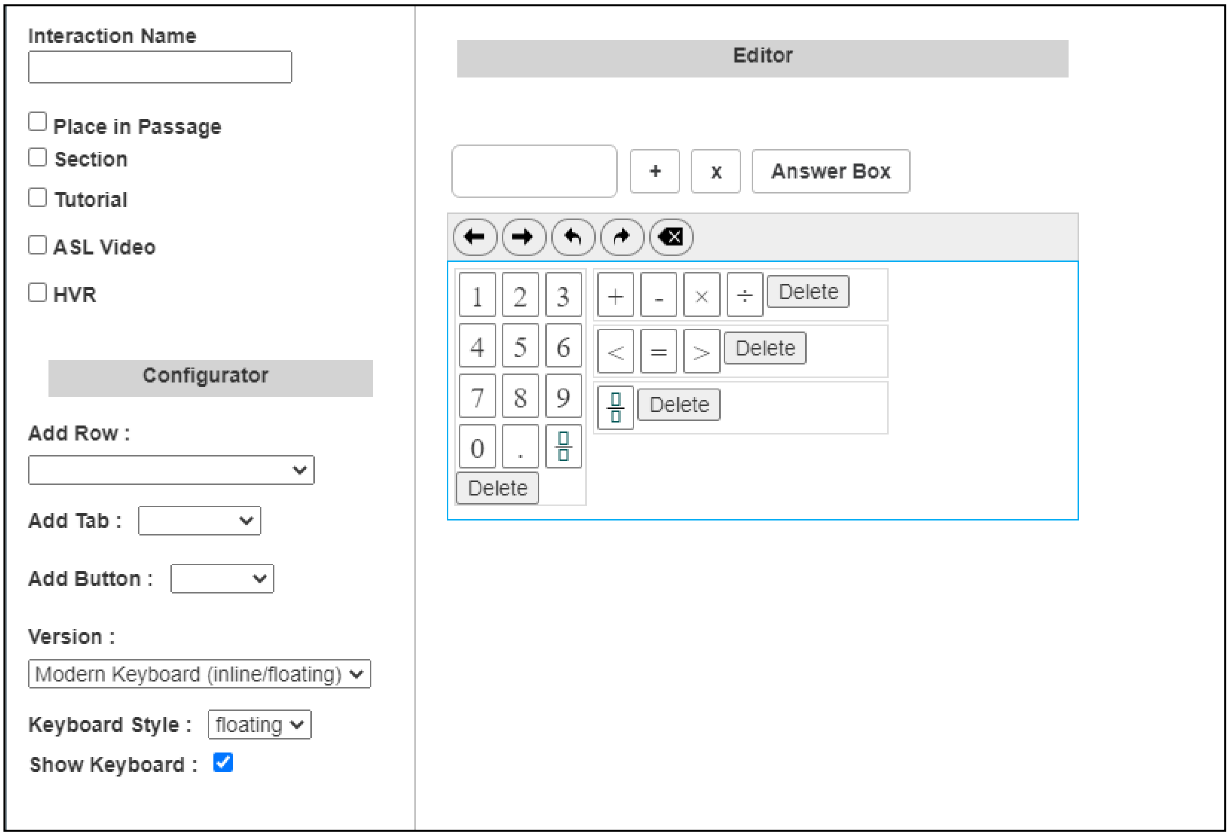
AND

- “5*k* – 20*y*”

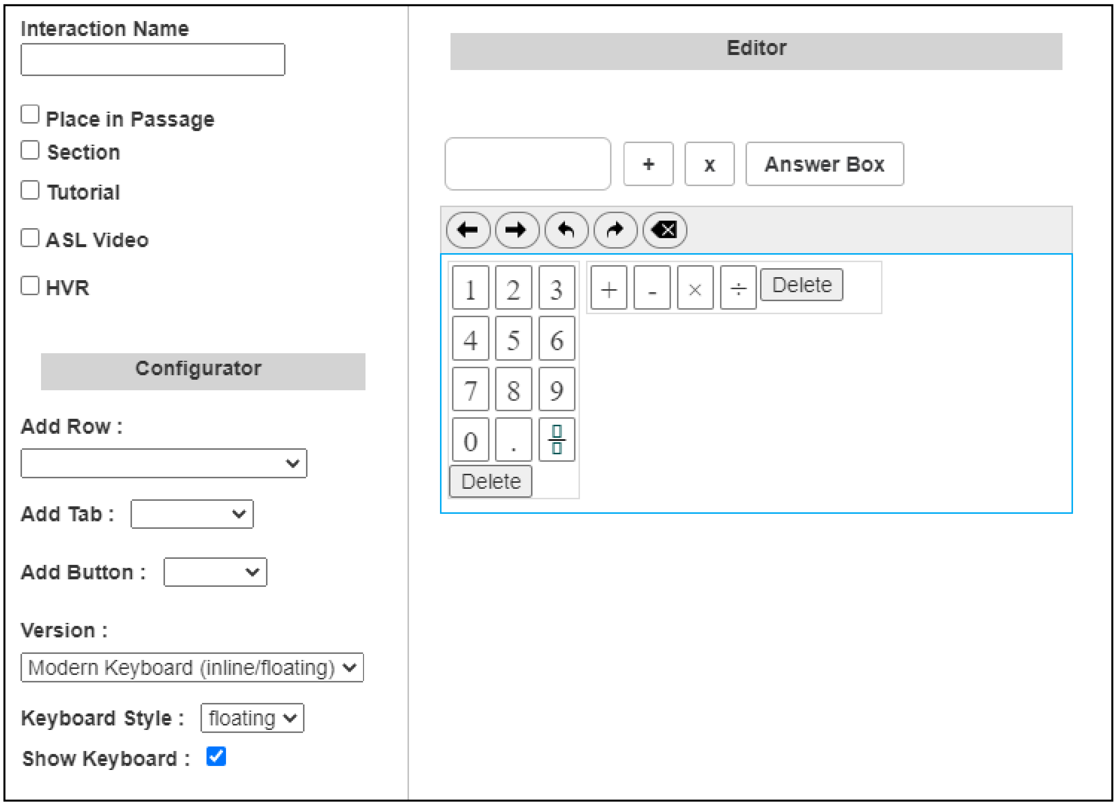
Keyboard
The keyboard is tailored to what the student needs to complete each interaction. Always include the absolute minimum number of buttons that the student will need.

The default keyboard includes a number pad, two fraction buttons, operators, and inequality symbols (see Default graphic below). *Always remove the standalone fraction button.* Also, remove the inequality symbols if they will not be used. This leaves the standard keyboard with the number pad, one fraction button, and the operators (see Standard—Revised Default graphic below).

Default


Interaction Name
Place in Passage
Section
Tutorial
ASL Video
HVR
Configurator
Add Row :
Add Tab :
Add Button :
Version :
Modern Keyboard (inline/floating)
Keyboard Style :
floating
Show Keyboard :
Editor
+
x
Answer Box
1 2 3
4 5 6
7 8 9
0 .
Delete
+ - × ÷ Delete
< = > Delete
Delete

Standard—Revised Default

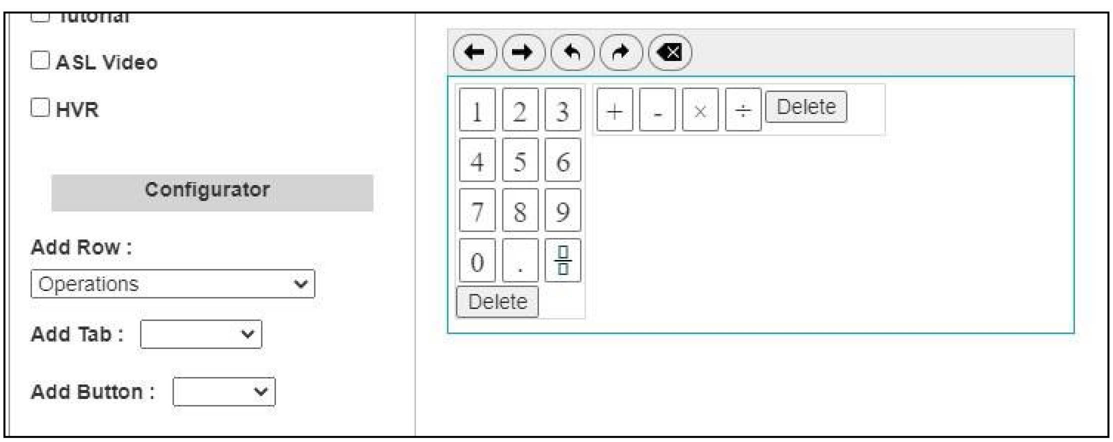


Operators at Different Grade Levels

- To change the operators on the keyboard, click "Add Row."

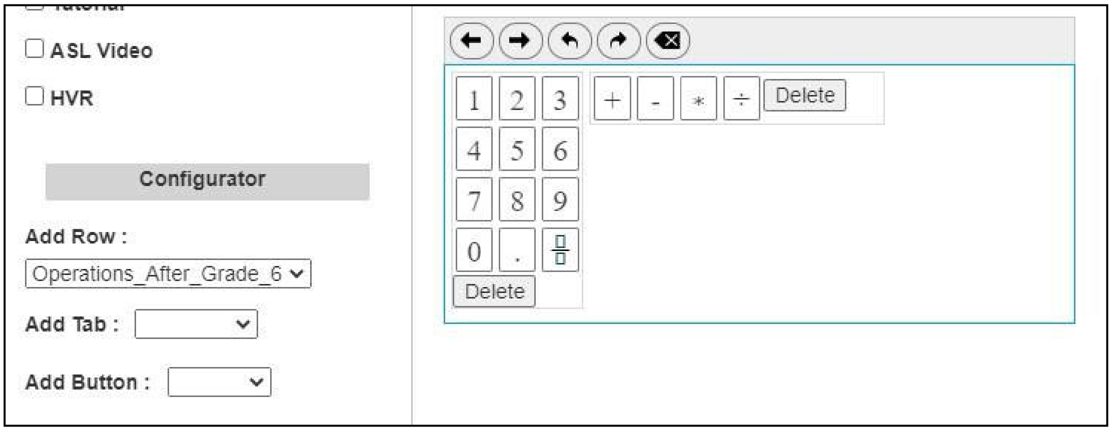
Operators for grades K–5

- This is the default. It can be selected as "Operations."
- The multiplication symbol is x.



Operators for grades 6–12

- Select “Operations_After_Grade_6.”
- The multiplication symbol is *.



F. Data Exploration Interactions (TUVA Graphs)

Task Directions

Graph 1 allows you to select which data to place along the *x*- and *y*-axes. You may make several graphs as part of your investigation of the data.

- To make a graph, click on an attribute and then click in the blank box that represents either the *x*- or *y*-axis.
- You can change the way the graphed data appear by using the toolbar at the top.
- You may place more than one attribute on each axis by dragging the attribute to the small "+" sign to the left of or below the current attribute.
- To change your selection, click on the small "x" to remove an attribute from that axis, and then add a new one.

Part III: Number Treatment Style Conventions

A. Treatment of Numbers

Note: This section provides GENERAL guidelines for the treatment of numbers. These guidelines are applicable to ALL content areas.

Words vs. Numerals

Use **words** for

- Numbers zero through nine, with the exceptions in this section.
- Numbers that appear as the first word in a sentence (content specialist determines exceptions).

Acceptable
10 mice are white.

Preferred
Ten mice are white.
OR
There are 10 white mice.

Use **numerals** for

- numbers 10 and above.
- numbers that precede abbreviated units of measure.
- numbers that precede or follow symbols: 10%, $20.00.
- numbers that appear in equations/expressions.
- numbers used to solve mathematical problems.
- numbers included in parts of published works: volume 2, chapter 4.
- dates and years: 1000 BC; December 1, 1975.
- times of day that precede the abbreviations a.m. and p.m.: 11 a.m., 3:00 p.m.
- telephone numbers.

In lists and series of numbers, use either words or numerals consistently.

Pat observes the following insects: 10 ants, 5 flies, and 2 crickets.
A circle graph is divided into five sections labeled 3, 6, 9, 12, and 15.

Note: The content specialist determines whether to use words or numerals when guidelines for the treatment of numbers contradict one another.

Ordinals

- Spell out ordinals first through ninth.
- Use numerals for ordinals 10th and above; when numerals are used, suffixes are set on the baseline, not in superscript.
- In lists and series of ordinals, use either words or numerals consistently.

The student finished the race in second place.
The 25th customer to enter the store today will win a prize.

Commas in Numbers

Use a comma in

- numbers with five or more digits: 50,000.
- numbers with four digits only if other numbers in the item have five or more digits.

The teacher has driven his car a total of 28,000 kilometers in three years. He drove 6,000 kilometers the first year.

- numbers written as words: one million, eighty-seven thousand, three hundred twenty-two.

Do **not** use a comma in
- numbers with four digits (unless other numbers in the item have five or more digits).

  The teacher drove her car 836 kilometers in August, 1027 kilometers in September, and 914 kilometers in October.

- compound measures, such as height measurements: 12 meters 50 centimeters—not 12 meters, 50 centimeters. (Note: In most cases, use 12.5 meters.)

Values Less Than One
- Use singular units of measure with values less than one: 0.25 gram, not 0.25 grams.
- Include a zero before the decimal point in decimal values less than one: 0.15, not .15.

Negative Numbers
- Use a mid-point en dash to indicate negative numbers. Which point has the coordinates (2, –5)?

Fractions
The content specialist determines whether fractions are spelled out or expressed as numerals.
- As words, fractions are hyphenated as nouns, adjectives, and adverbs. Two-thirds of the students in the class ride the bus.
- As numerals, fractions are stacked vertically and appear at 90% of the base text size:

14 pt. = 12.6 pt.

A student gave $\frac{1}{4}$ of her sandwich to her friend.

Percentages
- Use the word percent after a number word. Five percent of the dogs have spots.
- Use the word percentage, not percent, as a stand-alone term. What percentage of the cats are white?
- Use the percent symbol after a numeral: 5%. (See "Symbols and Special Characters" in Part V for the preferred styles for symbols and special characters.)

  Of the marbles in the jar, 40% are red and 60% are blue.

Exponents
Exponents and other superscripted characters are scaled to 70% of the base text size: 14 pt. = 9.8pt.

$s^2 \times 7 = 28$

Ratios
Use a colon in ratios. Do **not** insert a space before *or* after the colon.

The ratio of solute to red solvent is 1:4.

Coordinates and Ordered Pairs

- Enclose coordinates and ordered pairs in parentheses.
- Include a comma, followed by a space, after the first number.

  Point A has the coordinates (3, 4).

- Include a space after the name of a point that precedes coordinates or ordered pairs.

  Line m begins at point A (2, 5) and ends at point B (−1, −3).

Dates

- *Abbreviated years:* Avoid abbreviating years whenever possible. When a year is abbreviated, the first two numbers are replaced by an apostrophe (not an opening single quotation mark): the blizzard of ’76.
- *Months and days:* In running text, dates are written in the following form: February 10, 2012.
- *Centuries:* Centuries are spelled out and lowercase: the twenty-first century, nineteenth-century literature.
- *Decades:* Decades can be spelled out or expressed as numerals; if spelled out, they are lowercase: the nineties, the 1990s. (Note that no apostrophe is used in the plural form of decades.)
- *Eras:* Eras are expressed as numerals: 55 BC, AD 1066. (Note that BC and BCE follow the date, while AD and CE precede the date. All four abbreviations are uppercase with no periods.)

Times of Day

The content specialist determines how to present times of day in individual test items. The following conventions should be applied based on the presentation selected:

- Use numerals with the abbreviations a.m. and p.m. (Note that the abbreviations are lowercase with periods.) It is redundant to include phrases such as “in the morning,” “in the afternoon,” or “at night” after a.m. or p.m.

  The student wants to see a movie that starts at 4:10 p.m.

- Spell out numbers used with the term “o’clock.”

  The student leaves for school at eight o’clock.

- To avoid confusion, spell out the terms noon and midnight (in place of 12 a.m. or 12 p.m.).

  The student works from 6:30 p.m. to midnight.

B. Equations / Expressions and Patterns

General Guidelines

- In general, equations and patterns are 14 pt. Verdana; however, the font sometimes varies for equations and patterns that include symbols.
- In introductory statements, use the term "equation" or "expression" to refer to an equation or expression. Do not use the term "number sentence."
- Use the term "pattern" to refer to patterns of numbers and patterns of symbols.
- Use the term "step" to refer to the position of a term in a pattern: the fifth step in the pattern.
- In items, equations are center-aligned and can be given the headings "Equation 1," "Equation 2," etc.
- See "Graphics and Other Stimuli in Items" in Part I for additional guidelines.

Variables and Symbols

- In general, variables are lowercase and italicized. (However, variables in provided formulas can be uppercase or lowercase, as tradition and context dictate.)

  Solve for x.
  formula for area: $A = lw$

- In **grades 3–5**, use boxes to indicate missing/unknown values in equations.
- In **grades 6 and above**, use variables or boxes to indicate missing/unknown values in equations.

  $6 + n = 12$

- In all grades, use a question mark or underscored blank space to indicate missing terms in patterns. (The content specialist determines whether to underscore the question mark.)

  2, 4, ?, 8, 10

Operational Symbols

See "Symbols and Special Characters" in Part IV for a complete list of operational symbols used in Mathematics as well as the preferred styles for symbols and special characters used in item text and graphics. See "Words vs. Symbols" in this section for information about using words and symbols to identify geometric objects in running text.

Multiplication symbols.

- In grades 3–5, use the multiplication symbol.

  8×7

- In grades 6 and above, use the product dot or do not include a symbol. (Do not use the × symbol, except in scientific notation, to avoid confusing with the variable x.).

  $8 \bullet 7$
  $(10 - 2)(7)$

- In all grades, use the multiplication symbol in scientific notation.

  5.02×10^6

C. Units of Measure

When to Abbreviate

- Spell out units on their first usage in a cluster stimulus or in an item stem followed by the abbreviation in parentheses.
- Abbreviate units thereafter in item stems or options.

  Stephanie has 15 pieces of string. Each piece is 5 meters (m) long. How many meters of string does Stephanie have altogether?
  A. 25 m
  B. 50 m
  C. 75 m
  D. 100 m

- Spell out units in tables (See "Units of Measure" in Part IV for additional information.)
- Abbreviate units in graphics. (See "Units of Measure" in Part IV for additional information.)

Abbreviations

Note: Do not include periods in abbreviated units of measure.

Metric Units

Table 4 shows the correct abbreviations for metric units of measure.

Table 4. Abbreviations for metric units of measure

Unit	Abbreviation
Millimeter	mm
Centimeter	cm
Meter	m
Kilometer	km
Milligram	mg
Gram	g
Kilogram	kg
Milliliter	mL
Liter	L

kilogram-meter per second = kg·m/s

Here is a link to SI units to use as a resource:
https://www.nist.gov/pml/weights-and-measures/metric-si/si-units

Hyphenated abbreviations used with numbers as modifiers are not hyphenated.

Example: a 10 m pole, a 10-meter pole

Temperature Units

Table 5 shows the correct abbreviations for units of temperature.

Table 5. Abbreviations for units that measure temperature

Unit	Abbreviation
degrees Celsius	°C
Kelvin	K

Unit	Abbreviation
degrees Fahrenheit	°F

Note: Degrees Fahrenheit is preferred when discussing weather or body temperature.

Time Units

Table 6 shows the correct abbreviations for units of time.

Table 6. Abbreviations for units that measure time

Unit	Abbreviation
Day	day
Minute	min
Second	s

Unit	Abbreviation
Hour	hr
Month	mo
Year	yr

Plural Units

- Do not add an "s" for plurals of abbreviated units.

  Melissa is making 10 identical saltwater solutions. She needs 100 milliliters (mL) of distilled water to make 1 solution. How many milliliters of distilled water does she need to make 10 solutions?
  A. 10,000 mL
  B. 1,000 mL
  C. 100 mL
  D. 10 mL

- Use a singular verb with physical quantities. How many grams (g) of silver is produced?

Punctuation and Spacing

- Do not include periods in abbreviated units: cm, s, cm, m/s^2
- Do not include commas in compound measures, such as height measurements: 12 meters 50 centimeters—not 12 meters, 50 centimeters. (Note: In most cases, use 12.5 meters.)
- Include a space between numerals and abbreviated units, except in temperatures: 30 cm, but 90°F.
- In temperatures, do **not**
  - include a space between the numeral and degree symbol, or between the degree symbol and the unit: 0°C.
  - use a degree symbol with the abbreviation for kelvin: 223K not 223°K.
  - There is also NO space between number and degree symbol or directional in longitude or latitude measurements: 90°N.

Square and Cubic Units

- When units are spelled out, spell out the terms square and cubic.
- When metric units are abbreviated, use superscript to show square and cubic units.

  The student drew a square with a side length of 6 centimeters (cm). What is the area, in square centimeters (cm^2), of the student's square?

  A. 15 cm^2

  B. 30 cm^2

  C. 36 cm^2

  D. 54 cm^2

- When customary units are abbreviated, use sq and cu for units.

  83 sq m

Conversions

The content specialist determines whether to include conversions in items.

- When included, conversions are enclosed in brackets after the punctuation mark at the end of the stem. The conversion itself includes no punctuation.

  What is the volume of the rectangular prism?
  [1000 milliliters (mL) = 1 liter (L)]

- Use an equal sign in conversions that involve units of measure; always position the value with the smallest unit on the left side of the equal sign.

  What is the area, in square meters (sq m)?
  [100 centimeters (cm) = 1 meter (m)]

- Use the term "represents" in conversions that involve scales or that assign a value to a graphic.

  What is the total area of the grid? [" represents 1 unit]

Pi

If an approximation for pi is desired to be given in a particular item, the value of pi should also be enclosed in brackets at the end of the item stem. However, the value is stated as a sentence that ends with a period.

What is the height of the cylinder? [Use 3.14 for π.]

D. Preferred Language

Conditional ("if") Clauses
Recast conditional clauses (e.g., "If this happens …?") when possible. If a conditional clause cannot be avoided, position it at the end of the sentence.

Let x = 7. What is the value of y?
not
If x = 7, what is the value of y?

The pattern continues. Which shape will be in step 25?
not
If the pattern continues, which shape will be in step 25?

Table vs. Chart

- Use "table" when data are organized and related in some way.

  The student recorded the measurements in the Volume of Water vs. Height of Plants table.

- Use "chart" when data are not organized to emphasize comparison among discrete items or related in any way (e.g., data that are listed).

  The Fancy Pens chart lists the types and colors of pens the student can buy.

Percent vs. Percentage vs. %

- Use the word "percent" after a number word.
- Use the word "percentage" as a stand-alone term: a percentage of students.
- Use the percent symbol after a numeral.

  A student has 20 folders. Each folder is either red, green, or yellow. Twenty percent of the folders are red. Forty percent of the folders are green. What percentage of the folders are yellow?
  A. 20%
  B. 30%
  C. 40%
  D. 50%

Constructed-Response Items

- Include units of measure in the stem so that students are not penalized for omitting units from their responses. Also, CR stems should be worded as imperatives (e.g., "Calculate the area"), not questions (e.g., "What is the area?").

  Calculate the area, in square meters (sq m), of the garden.

- In sentences that refer to item parts, the word "part" is lowercase and the part letter is capitalized.

  Identify the statement that supports the choice in part A.

- The content specialist determines the language of statements that ask students to justify their answers.

  Show your work. Explain your reasoning.
  Show or explain how you got your answer.

Show or explain how you know your answer is correct.

Part IV: Graphic Specifications

Note: The specifications in this section are for all graphics, including graphics used in technology-enhanced interactions (TEIs).

A. Text Elements

This section provides specifications for text elements that appear in graphics.

Fonts
In general, text in graphics is Verdana. However, exceptions are made for graphics that require a special look (e.g., advertisements, posters). Table 7 shows general font specifications for different text elements in graphics.

Table 7. General font specifications for text elements in graphics

Font Specifications	
Text Element	**Font**
Title	- 14 pt. Verdana Bold - Title case
Headings (e.g., axes headings, column headings)	- 14 pt. Verdana Bold - Title case
Labels and text	- 14 pt. Verdana - Sentence case
Credit lines	- 10 pt. Verdana - Lowercase

Note: At this time, Verdana is specified as the primary font for test content.
However, another font may be chosen upon further analysis of the effects that fonts have on readability and students' ability to retain information.

Symbols and Special Characters

The table that follows shows the preferred styles for symbols and special characters. These specifications apply both to symbols in graphics and symbols in text, with the exceptions noted.

- In graphics, the size and style (e.g., boldface, italic) of a symbol depends on where it appears in the graphic. For example, a symbol that is part of a title is 14 pt. and boldface. Use Table 7 in the previous section to determine the correct size and style of symbols.
- In items, symbols are the same size and style as the surrounding text.

Table 8. General font specifications for symbols and special characters in graphics and text

Font Specifications for Symbols and Special Characters		
Symbol/Character	**Font**	**Description**
&	Verdana	- Ampersand - Do not use in science
©	Verdana	- Copyright symbol - Used in acknowledgments and credit lines
$2.00 50¢	Verdana	- Dollar sign/cent symbol - Used in dollar amounts
%	Verdana	- Percent symbol - Used in percentages
’	Verdana	- Smart (curly) apostrophe - Used in possessives
′	Verdana	- Prime mark - Used to indicate prime numbers
ʻ	Verdana	- Okina - Glottal stop used to spell Hawaiʻi
0°C 45° angle	Verdana	- Degree symbol - Used in temperatures and angle measures - No space between number and degree symbol or between degree symbol and unit of measure
+	Verdana	- Addition symbol - Used in equations/expressions
–	Verdana	- En dash - Used as subtraction symbol in equations/expressions; also used in number ranges and with negative numbers
×, •	Verdana	- Multiplication symbol and product dot - Used in equations/expressions

Table 8. General font specifications for symbols and special characters in graphics and text *(cont.)*

Font Specifications for Symbols and Special Characters		
Symbol/Character	**Font**	**Description**
÷	Verdana	- Division symbol - Used in equations/expressions
=	Verdana	- Equal sign - Used in equations/expressions
$\frac{1}{2}$	Verdana	- Vertically stacked fraction - Scaled to 90% of text size: 16 pt. = 14.4 pt.; 14 pt. = 12.6 pt.
π	Symbol Std.	- Pi - Not italicized - Used in equations/expressions
~	Verdana	- "Similar to" symbol - Used to indicate similar lines, shapes, and angles
(4, 3)	Verdana	- Coordinates and ordered pairs - Enclosed in parentheses - Comma, followed by space, after first number
1:2	Verdana	- Ratio - No space before *or* after colon
$V = l \times w \times h$	Verdana	- Variables - Uppercase or lowercase, as tradition and context dictate - Italicized - Used in equations/expressions and formulas
x, *y*	Verdana	- *x*-axis and *y*-axis labels - Lowercase - Italicized - Used to label *x*- and *y*-axes in line graphs, scatter plots, and coordinate grids

Table 8. General font specifications for symbols and special characters in graphics and text *(cont.)*

Font Specifications for Symbols and Special Characters		
Symbol/Character	**Font**	**Description**
A, B, C	Verdana	- Point label - Boldface, italicized, uppercase letter (in graphics only; see "Points" in Part IV for point labels in text) - Used to label points and other geometric objects
1st, 2nd	Verdana	- Ordinals - Positioned on baseline (not superscripted)
13^2	Verdana	- Superscript - Scaled to 70% of text size: 16 pt. = 11.2 pt.; 14 pt. = 9.8 pt. - Raised by 33% with a baseline shift of +6
H_2O	Verdana	- Subscript - Scaled to 70% of text size: 16 pt. = 11.2 pt.; 14 pt. = 9.8 pt. - Lowered by 33% with a baseline shift of –6
9:00 a.m. 3:00 p.m.	Verdana	- Used to indicate times of day - Lowercase (not small caps)
100 BC/BCE AD/CE 1800	Verdana	- Used to indicate eras, epochs, etc. - Uppercase (not small caps)

Note: Symbols and special characters are used at the content specialist's discretion.

B. Graphic Size

Graphics should be

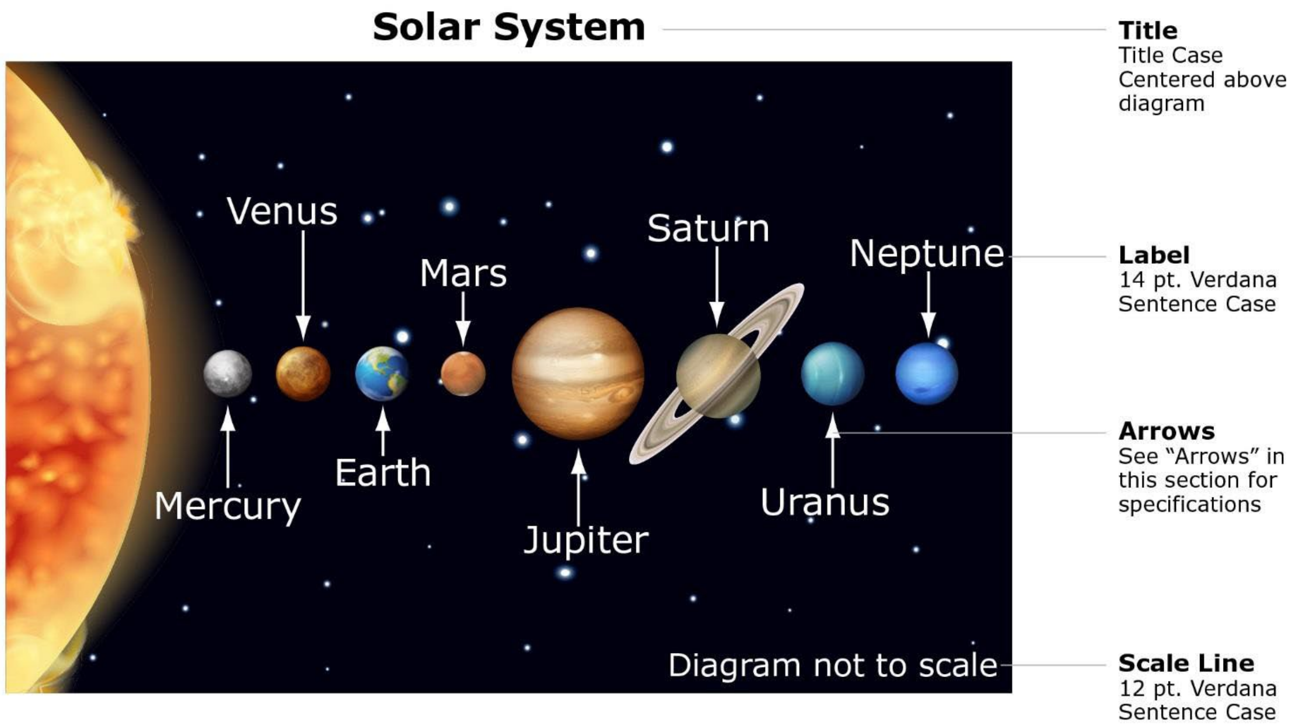
- large enough for students to read text and view content.
- small enough to fit in the viewing area on the computer screen. Students should not have to use horizontal scrolling to see an entire graphic.
- free of excess white space. Condense graphics as much as possible without compromising legibility and font size.

About Image Dimensions
The table below provides the recommended maximum image dimensions (in pixels) you should use for each item layout in order to avoid forcing students to view the item's content on a standard 1024 x 768 monitor. These dimensions should not be regarded as absolute restrictions but as suggested guidelines to consider when inserting images in IAT.

	Stem Max Image Width	Stem Max Image Height	Passage Max Image Width	Passage Max Image Height
Layout 1	600	590		
Layout 2	400	450		
Layouts 3 & 4	400	450		
Layout 5	600	400		
Layout 6	600	400		
Layout 8				
Layout 12				
Layout 13				
Layout 14	600	450		
Layout 15				
Layouts 11 & 17	360	250	590	590
Layout 21	570	250	400	590
Layout 22				
Layout 23	960	250	980	250
Layout 24 & 29	600	250	380	590
Layout 25	670	250	290	590
Layout 26	470	250	500	590
Layout 27 & 28	270	250	700	590
Layout 32 & 33	960	700		
Layout WAI	960	700	960	700

Scaled Graphics

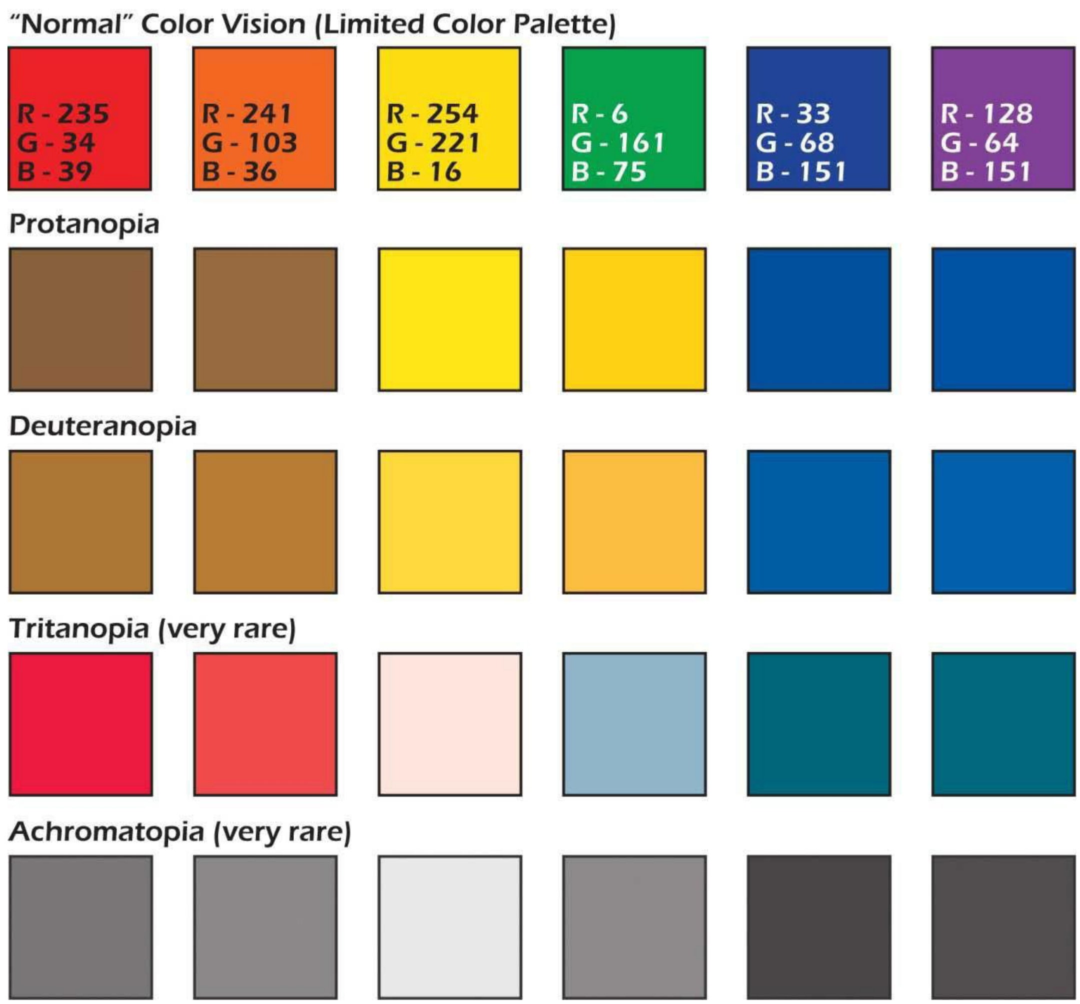
Graphics that are not drawn to the correct scale are labeled with the phrase “Diagram not to scale.” Note that “Diagram not to scale” is not punctuated.



C. Graphic Colors

Although color can be used to enhance the appearance of graphics, it should be used sparingly (at the content specialist's discretion). The use of color introduces special considerations for students with color-vision deficiencies. Use the guidelines that follow to help avoid creating graphics that present challenges for these students.

- Do not design graphics that require students to rely solely on color to obtain information.
- Consider combining colors with pattern fills to assist students who might have trouble using color alone to differentiate graphic elements, such as bars on a graph.
- Use a color-vision deficiency simulator, such as Vischeck or Coblis, to check colors in graphics for possible issues.
- Use the limited color palette shown in the top row of the diagram that follows. The other rows in the diagram show how the colors in the limited palette appear to students with certain color-vision deficiencies.



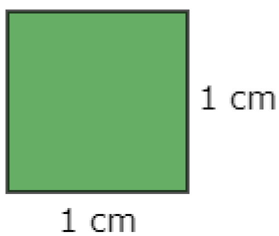
D. Common Graphic Elements

This section provides specifications for elements that often appear in graphics.

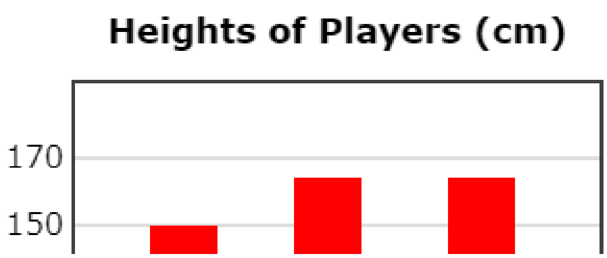
> Note: Within individual graphics, the sizes of elements such as points, tick marks, and tallies may be adjusted as needed to emphasize or to de-emphasize certain content in a graphic.

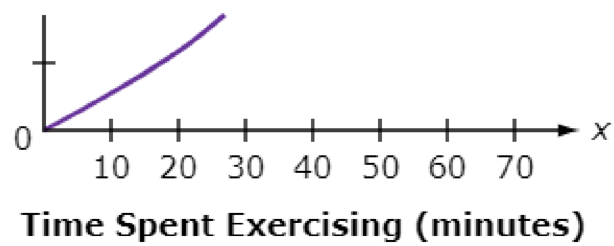
Alignment
Graphics within both the stimulus and the items should be centered on the page.

Units of Measure
In graphics, units are abbreviated or expressed as symbols. (See Part IV for the correct abbreviations of units.) The abbreviated unit or symbol is not preceded by the word *in*.



In graphs and tables, units are enclosed in parentheses after titles or headings.





In tables, do not include the unit in both the column/row heading and in the individual cells in the column/row.

Incorrect:

Correct:

Shots Made

Game	Shots Made (%)
1	65%
2	70%

Shots Made

Game	Shots Made (%)
1	65
2	70

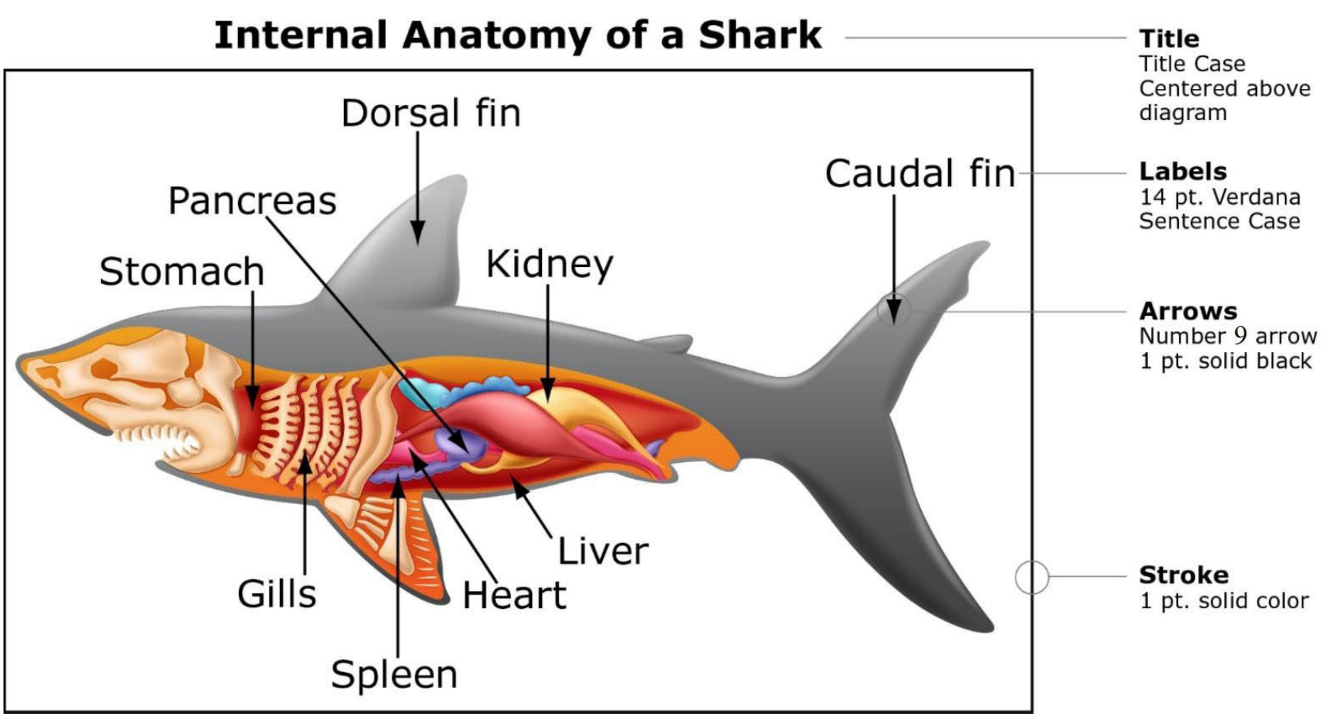
The diagram that follows shows some specifications for diagrams.

- A diagram is art used to describe a scientific system; therefore, the diagram must be scientifically accurate, in realistic perspective, and in scale.
- Tabletops are indicated only by a horizontal line at the back of the table. It is generally not necessary to show the legs or front edge of the table. The tabletop is labeled as "Tabletop" without an arrow.
- Diagrams describing a controlled experiment setup should show the system being investigated with both the manipulated and responding variables.
- All the materials of an experiment do not need to be in the diagram.
- Students, when appropriate, may be included in a diagram but the students must be realistic and grade appropriate.
- Text in diagrams should be phrases, not sentences.
- Any diagram in an item that comes from a diagram in the stimulus should be the same.
- Graphics and diagrams are centered.

Arrows

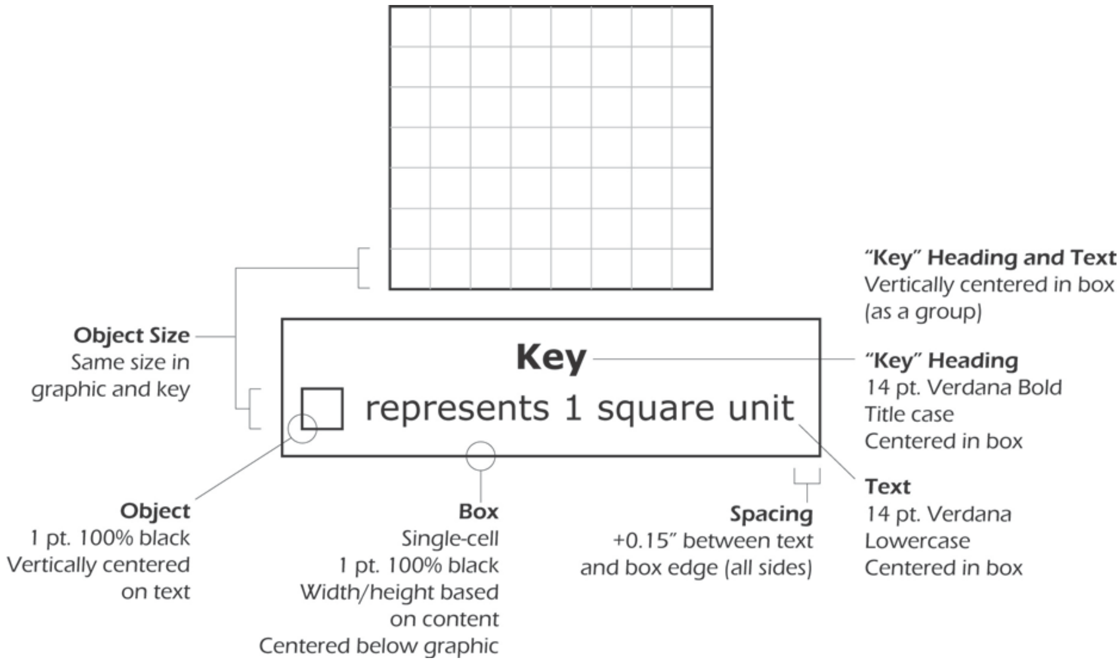
The diagrams that follow show specifications for arrows and arrowheads used in graphics to label diagrams.

- Use number 9 arrowhead in Illustrator.
- The arrowhead of the leader from the label to the object being labeled should touch the outer rim of the object being labeled, not inside the object unless what is being labeled is inside an object. For example, a beaker partially filled with a liquid with an arrow labeling the liquid.
- Arrows may be any size or shape as needed in a specific diagram.
- Curvy arrows are no longer used in science assessments. We are still working to pull together some accurate examples.



Keys and Scales

Keys and scales are used to provide information that helps students understand graphics. The diagram that follows provides specifications for keys and scales that appear in graphics.

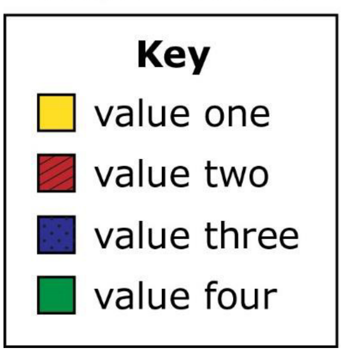


Key vs. Scale

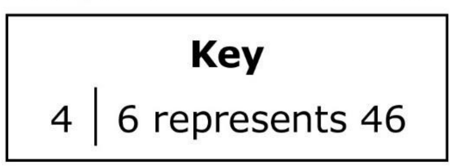
Use a key to provide students with information that helps them identify parts of a graphic or interpret information in a graphic. Use a scale to provide students with ratios and conversions.

In the diagrams that follow, Example 1 tells students the values of graphic elements (e.g., bars in a graph, parts of a shape) filled with colors and patterns; Example 2 tells students how to interpret information in a stem-and-leaf plot; and Example 3 provides students with a ratio for converting centimeters to kilometers.

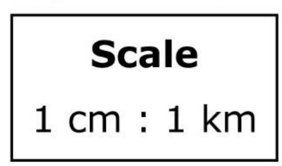
Example 1: Patterns



Example 2: Stem-and-Leaf Plot



Example 3: Scale/Ratio



E. Photographs and Raster Images

Table 9 provides general specifications for scanning photographs and raster images. Certain specifications differ for computer-based testing (CBT) and print-based testing (PBT). Raster images should not be converted to a different form like .svg.

Table 9. CBT and PBT specifications for photographs and raster images

Specifications for Photographs and Raster Images	
Specification	**Requirements**
File format	- CBT: SVG, PNG - PBT: SVG, PNG
Image resolution	- CBT: 72 dpi - PBT: 300 dpi
Color mode	- CBT: RGB - PBT: CMYK
Dimensions	- Based on test content
File Size	- < 1 Mb

Note: Always obtain a high-resolution image that meets the requirements for both CBT and PBT.

Image Improvement

All scanned images should be optimized to represent an ideal tonal range. When scanning images, eliminate any trace of moiré patterns (the line screens that appear when a printed image is scanned). Use the following techniques to help minimize the appearance of moiré patterns:

- Scan images at a 45° angle.
- Set the scanning software to compensate for line screens.
- Apply the Gaussian Blur filter in Adobe Photoshop.

Credit Lines

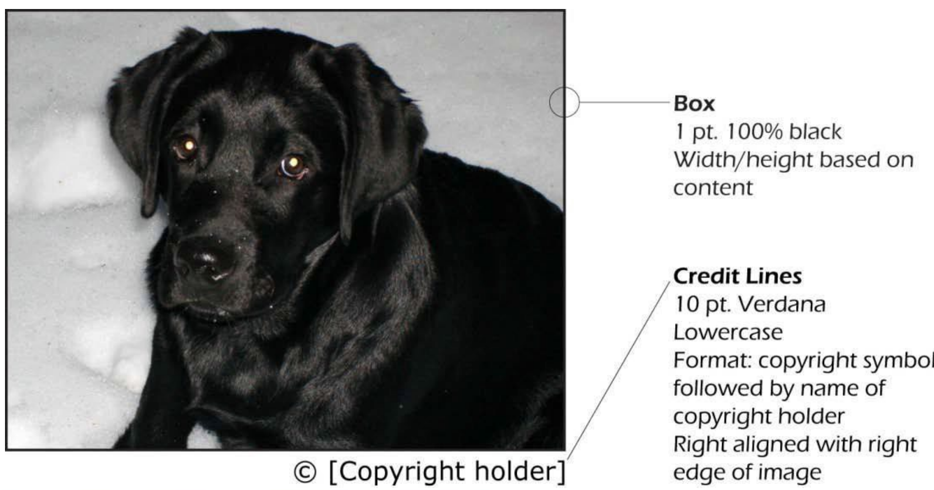
A credit line must be included for all images taken from copyrighted sources and those with Creative Commons licenses, including print publications, the Internet, stock photo agencies or discs, and other commercial and noncommercial sources. For images that do not appear in selections, credit lines should appear as shown in the examples below. (For information about images that appear in selections, see "Acknowledgments" in Part III.) All photographs and raster images should be enclosed in a box, as shown below.

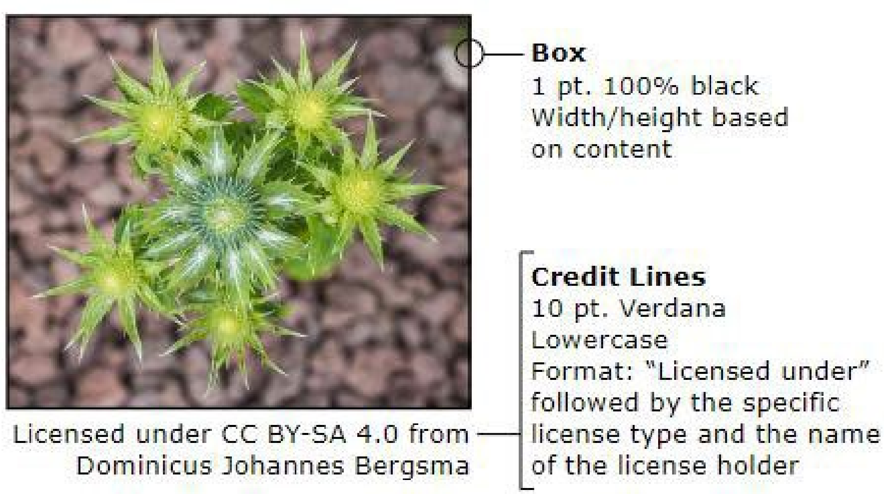
A credit line should be added by the graphics team as a caption that is part of the image. Credit lines should not be done in the IAT Editor.

Copyright is represented by the copyright symbol. Creative Commons licenses are represented by text in the format of "Licensed under CC BY-SA 2.0," indicating the type of Creative Commons license the image has.

For any license before Creative Commons 4.0, the credit line should include the name of the image. In instances where there are multiple images and one is a 4.0 or later and another is 3.0 or earlier, list the image name for both to be consistent within the item.

The Copyright Attribute in ITS should include the original name of the image, the owner of the image/copyright or license holder, a link to the original image, and a link to the copyright or license type.

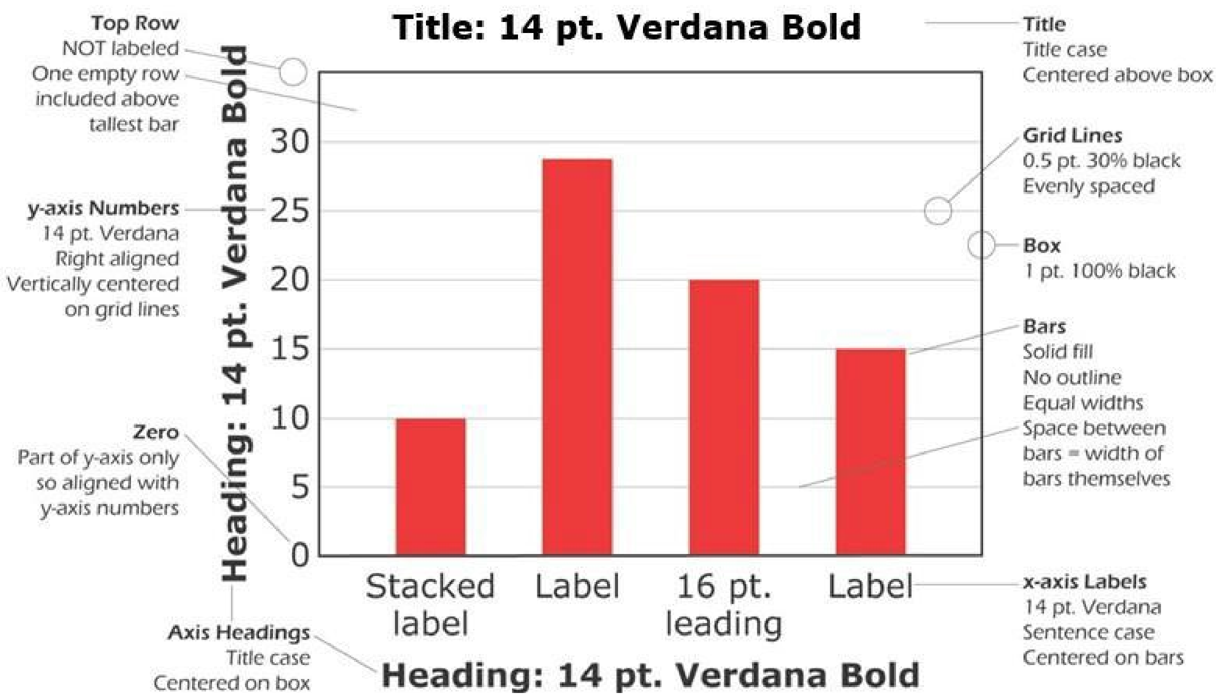


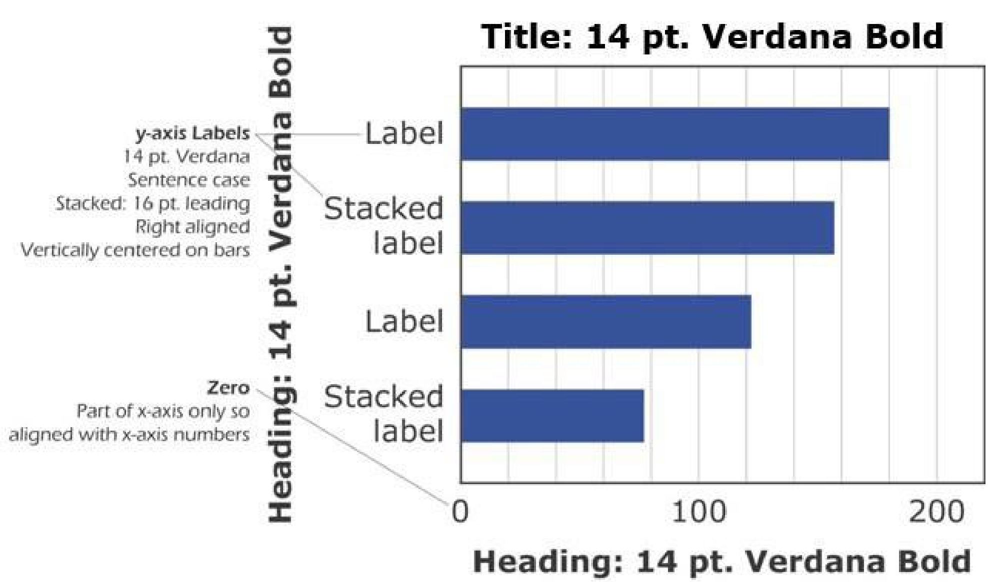


F. Graphs

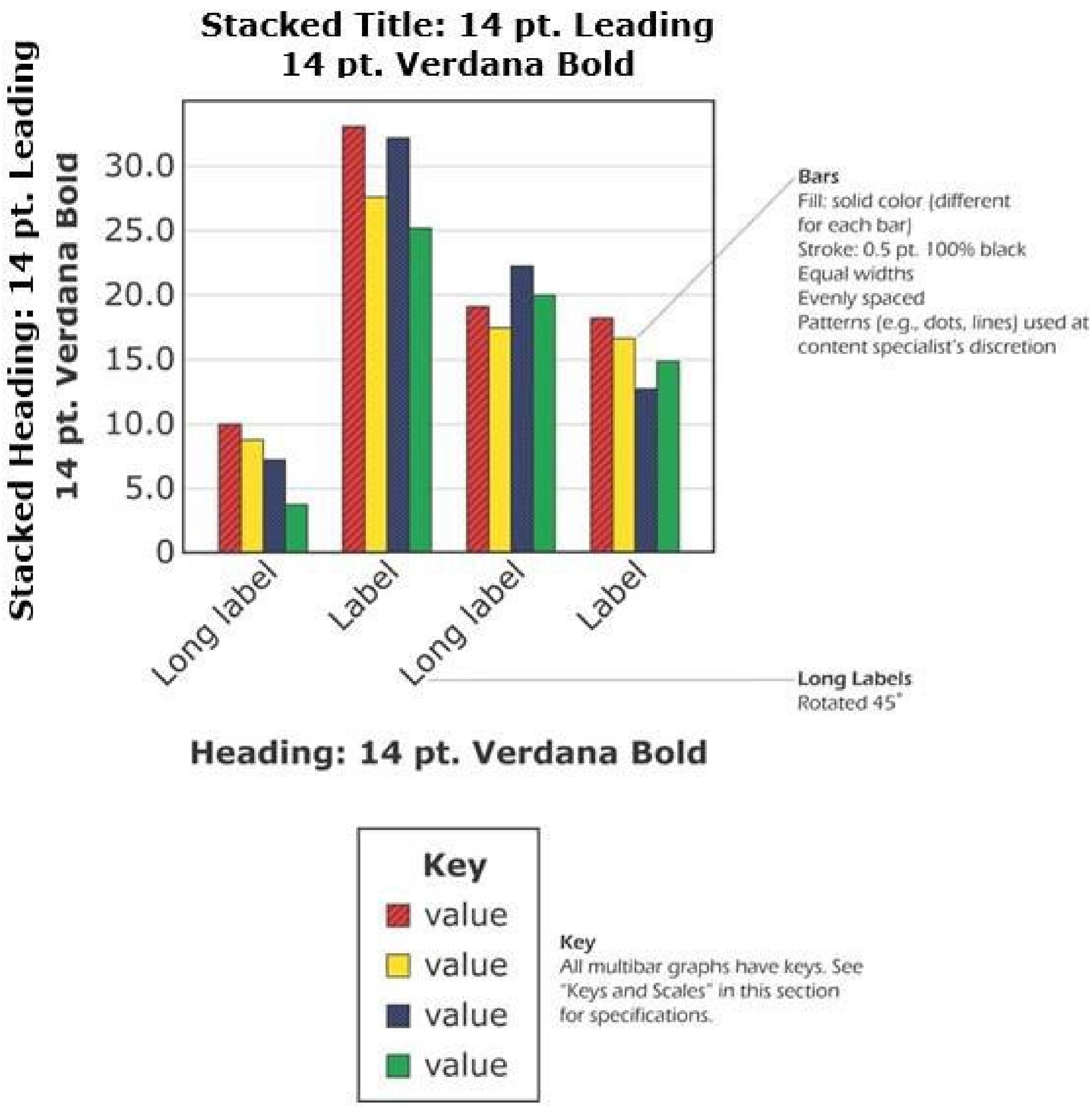
The diagrams in this section provide specifications for bar graphs, histograms, circle graphs, line graphs, and scatter plots.

Bar Graphs

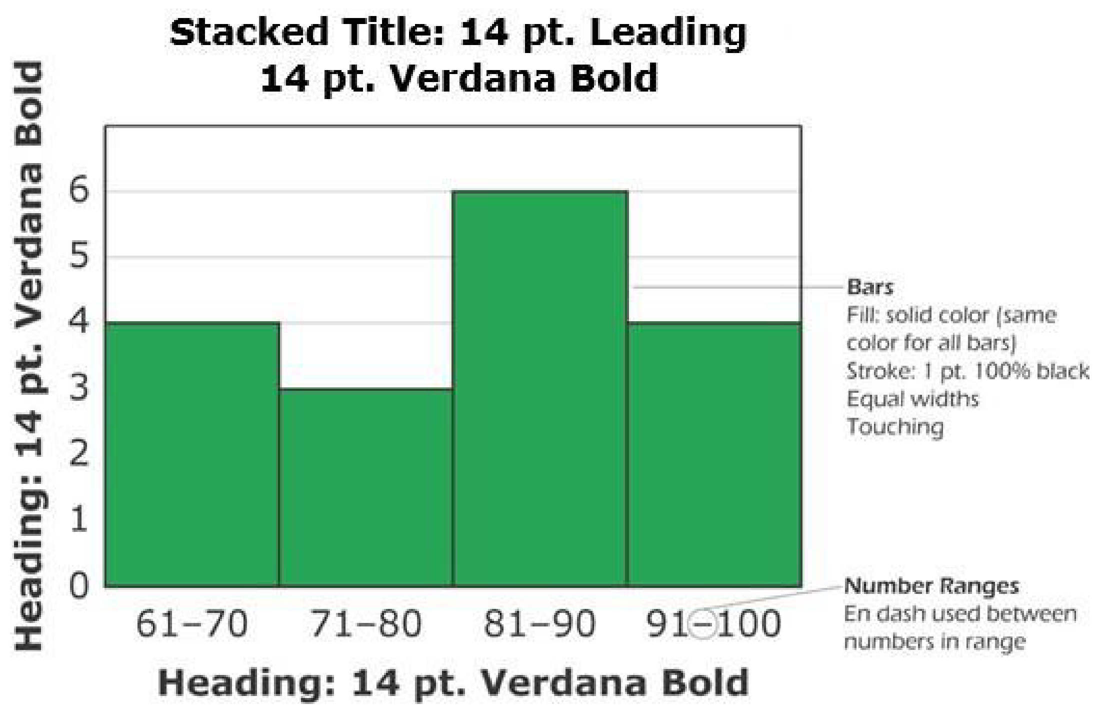




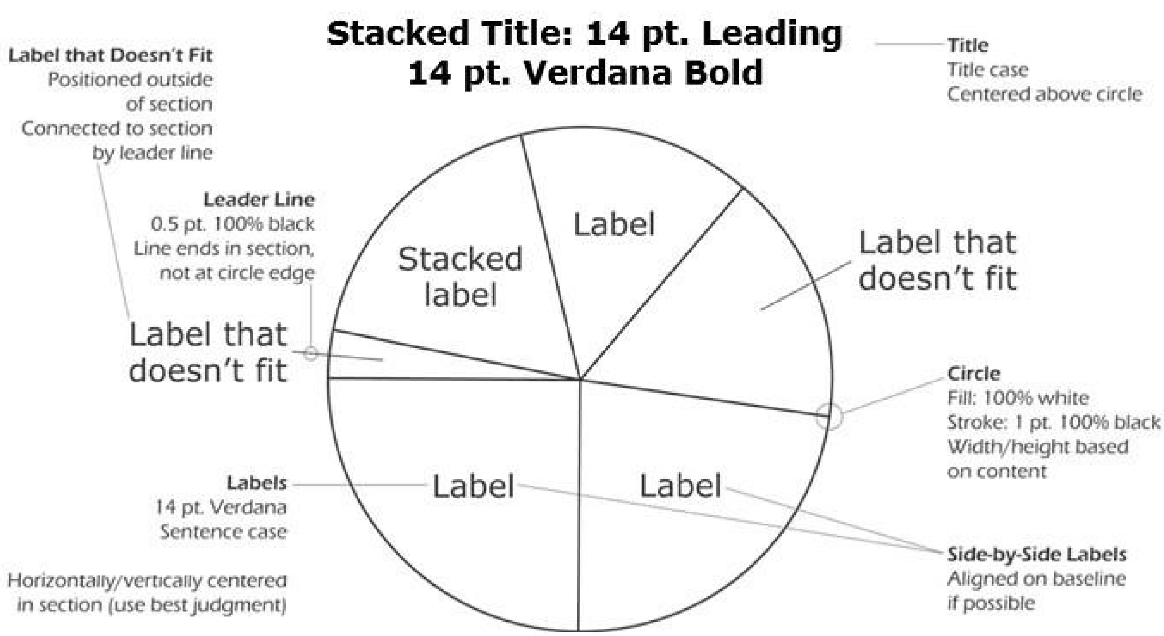
Multibar Graphs



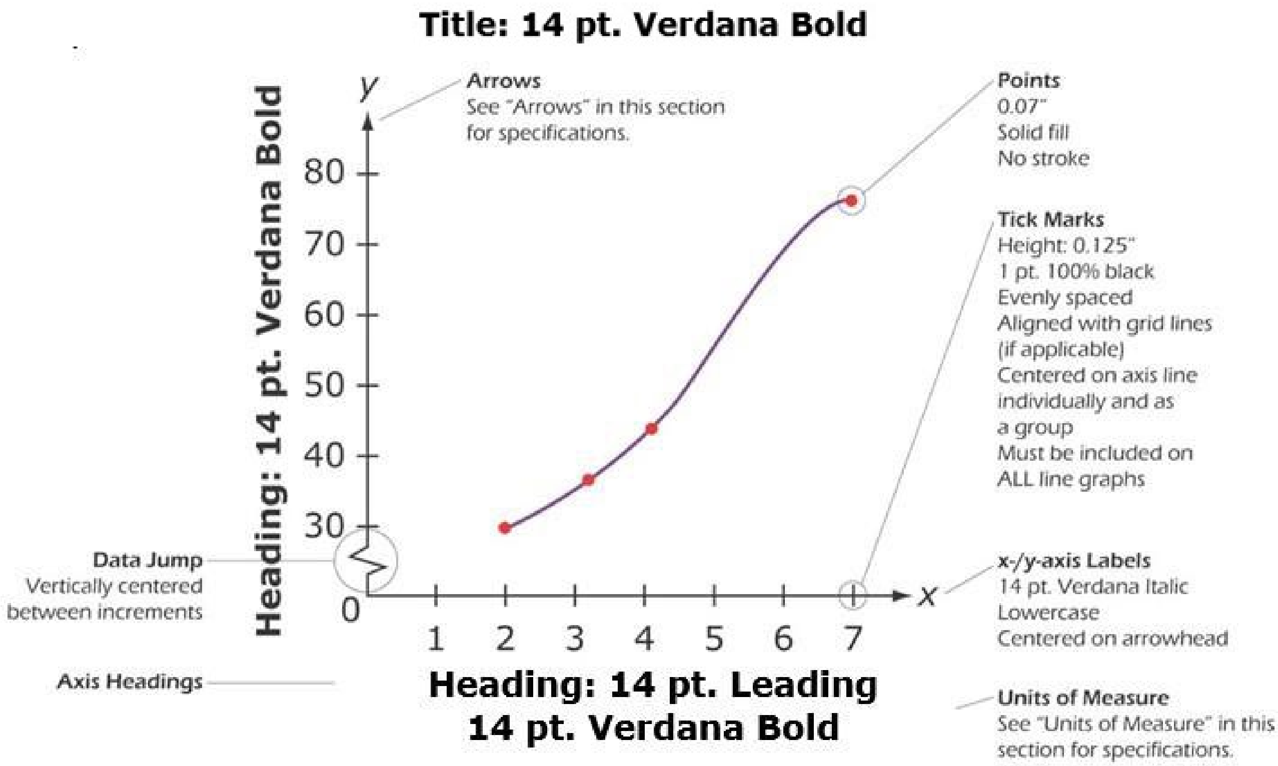
Histograms

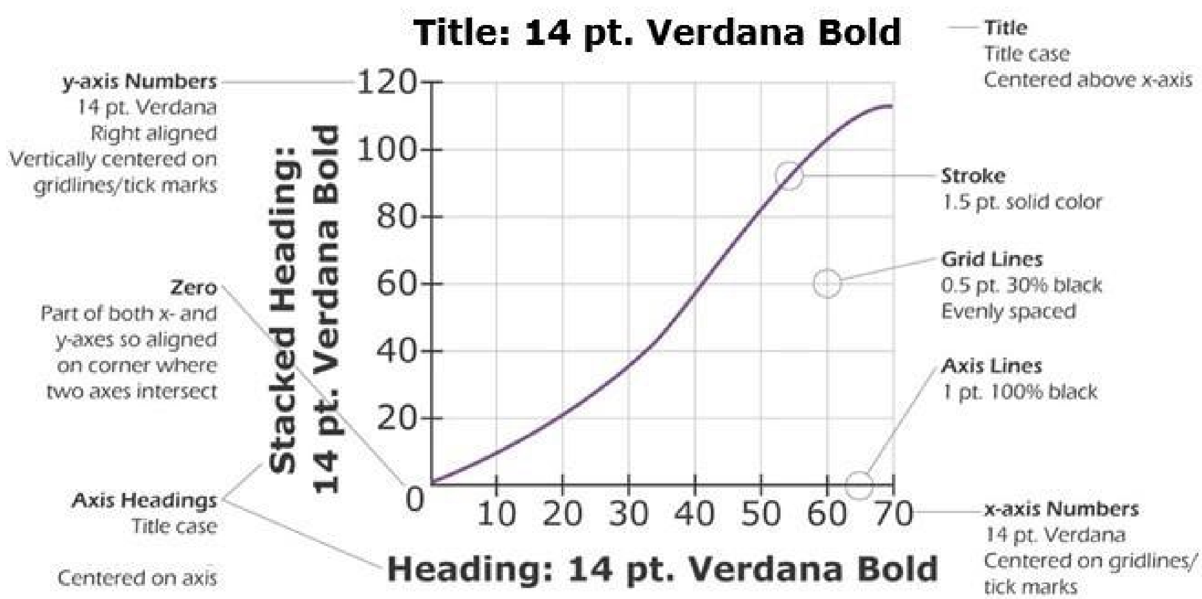


Circle Graphs

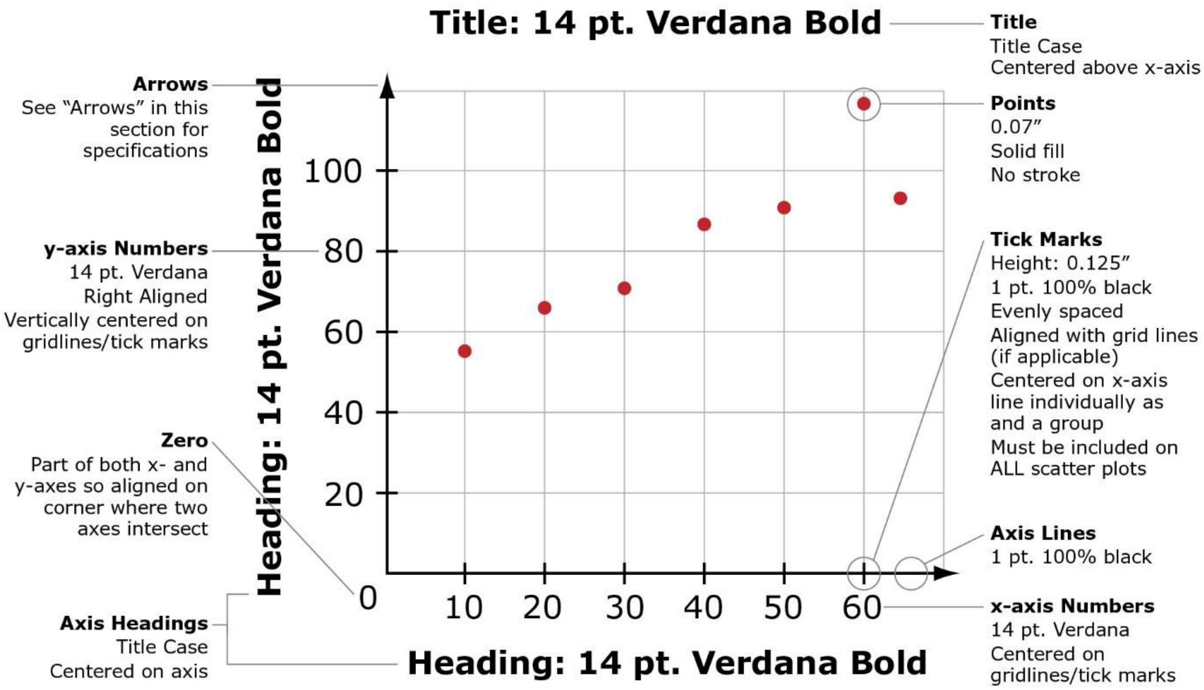


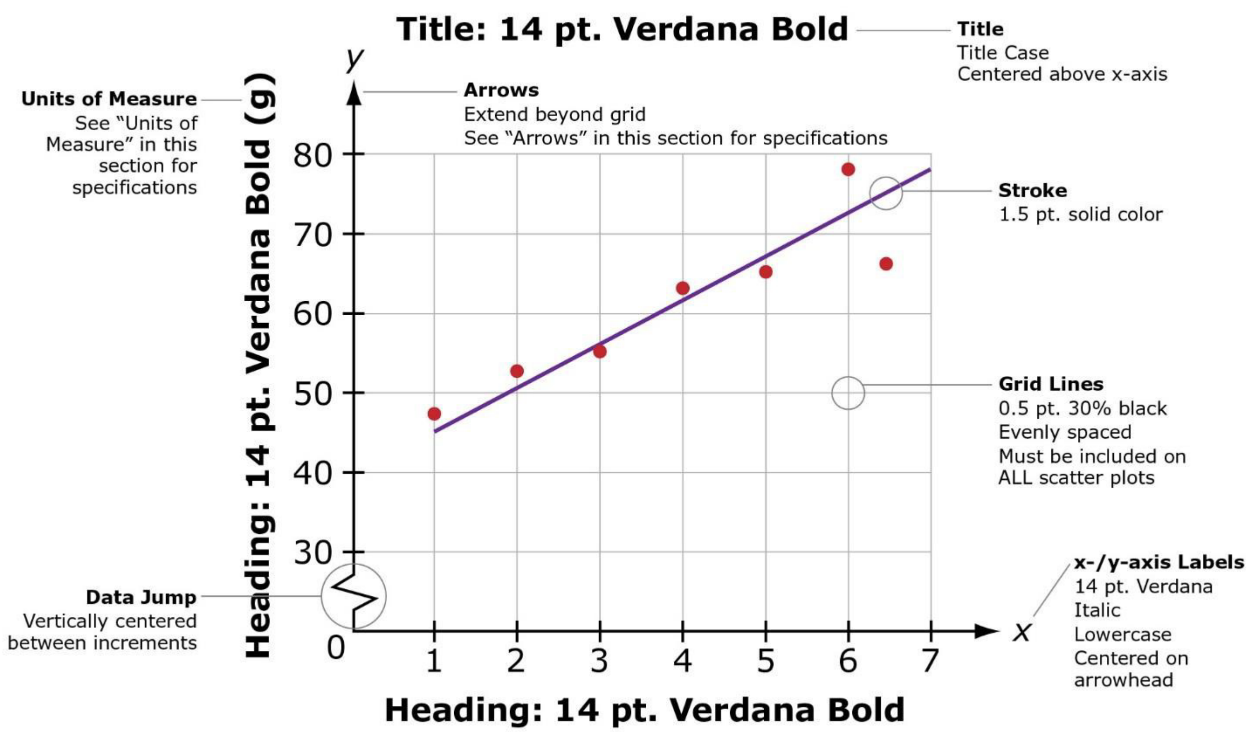
Line Graphs


Title: 14 pt. Verdana Bold
Arrows
See "Arrows" in this section for specifications.
Points
0.07"
Solid fill
No stroke
Tick Marks
Height: 0.125"
1 pt. 100% black
Evenly spaced
Aligned with grid lines (if applicable)
Centered on axis line individually and as a group
Must be included on ALL line graphs
Data Jump
Vertically centered between increments
x-/y-axis Labels
14 pt. Verdana Italic
Lowercase
Centered on arrowhead
Axis Headings
Units of Measure
See "Units of Measure" in this section for specifications.
Heading: 14 pt. Verdana Bold
Heading: 14 pt. Leading
14 pt. Verdana Bold
y
x
80
70
60
50
40
30
0
1
2
3
4
5
6
7


Title: 14 pt. Verdana Bold
Title
Title case
Centered above x-axis
y-axis Numbers
14 pt. Verdana
Right aligned
Vertically centered on gridlines/tick marks
Stroke
1.5 pt. solid color
Grid Lines
0.5 pt. 30% black
Evenly spaced
Zero
Part of both x- and y-axes so aligned on corner where two axes intersect
Axis Lines
1 pt. 100% black
Stacked Heading:
14 pt. Verdana Bold
Axis Headings
Title case
Centered on axis
x-axis Numbers
14 pt. Verdana
Centered on gridlines/tick marks
Heading: 14 pt. Verdana Bold
120
100
80
60
40
20
0
10
20
30
40
50
60
70

Scatter Plots





G. Tables and Charts

The diagrams in this section provide specifications for tables and charts, including pictographs and tally charts.

Text Alignment in Tables

Left align text within a cell when there is more than one word.

Table 1. Title

Text entry here	
Longer text entry here	
Each sentence cased	

Center text within a cell when there is:

- a single word or number
- a combination of words and numbers
- a combination of fractions and mixed numbers

Fractions and Mixed Numbers
Centered

Fractions	Mixed Numbers
$\frac{1}{3}$	7
$2\frac{3}{5}$	$\frac{1}{4}$
$\frac{3}{16}$	300.00

In columns with numbers only, center the widest number and align other numbers on the ones place or decimal point.

Table 2. Title

Longest number centered	100	52.8
Rest aligned on ones, decimal, or symbol	2	325.25
	22	1.5

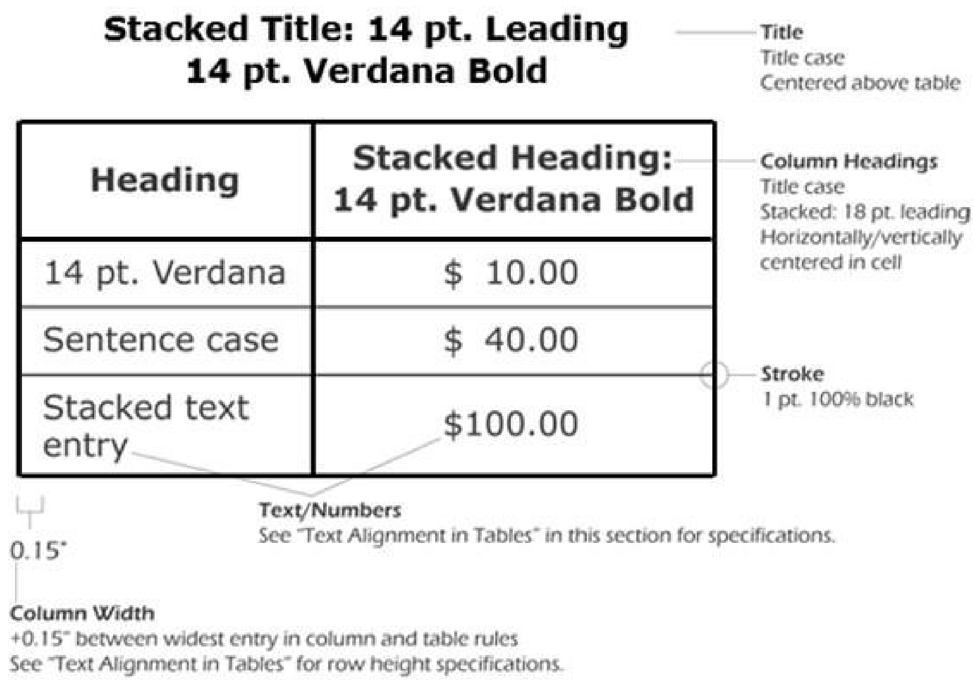
In columns with currency only, center the widest value, then:

- Align the dollar signs.
- Align dollar amounts on the decimal point.

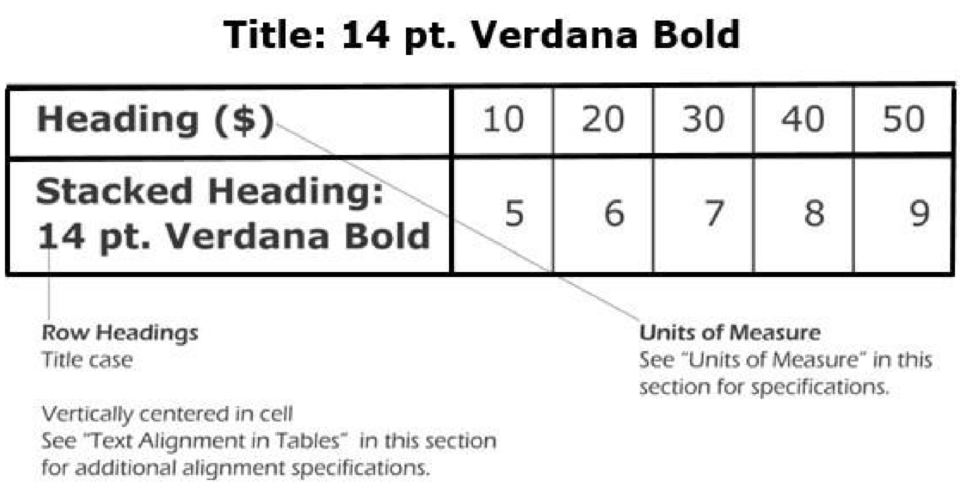
Table 1. Title

Dollar signs left-aligned	$12,540.00
Dollar amounts aligned on the decimal point	$ 25.00

Tables

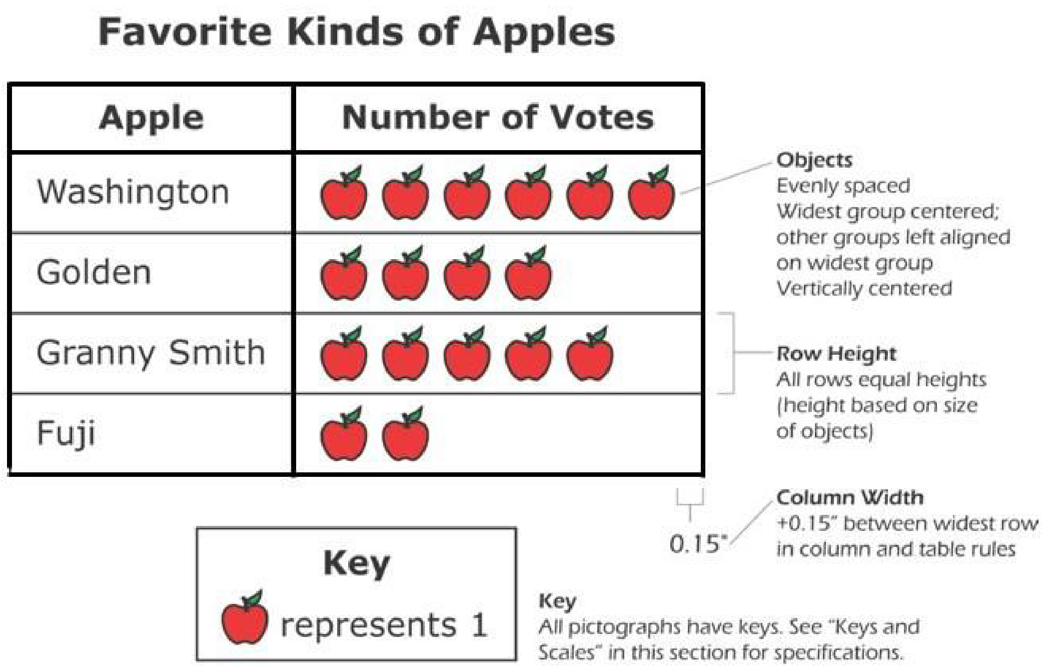


Note: If a cell entry begins with a numeral followed by text, lowercase the first word of the text, just as if the number were spelled out, e.g., use "10 grams," as you would if it were "Ten grams."



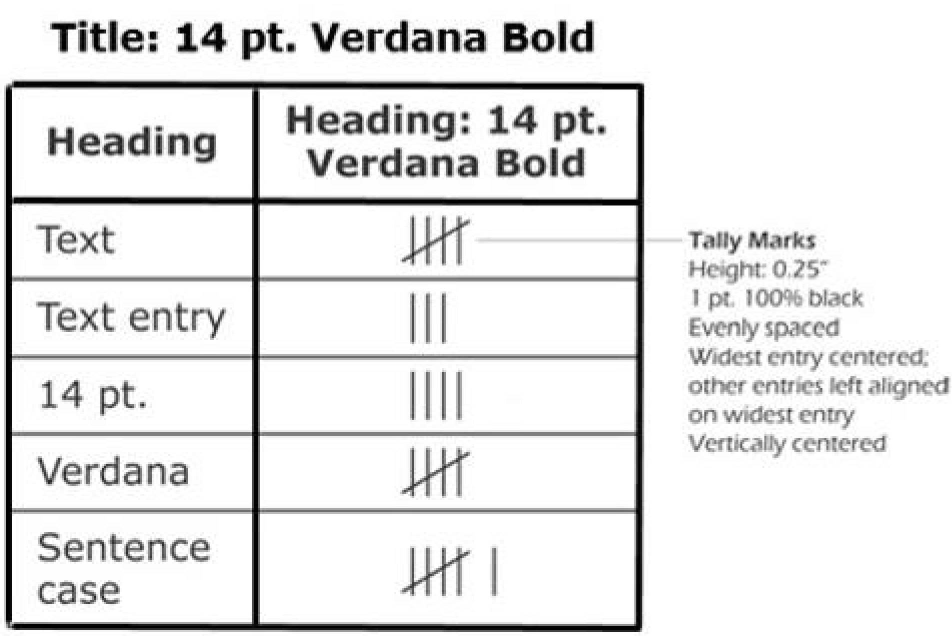
NOTE: ALL TABLES, EXCEPT FOR MATCHING ITEM TABLES, REQUIRE TITLES. TABLES ARE ALL CENTERED.

Pictographs



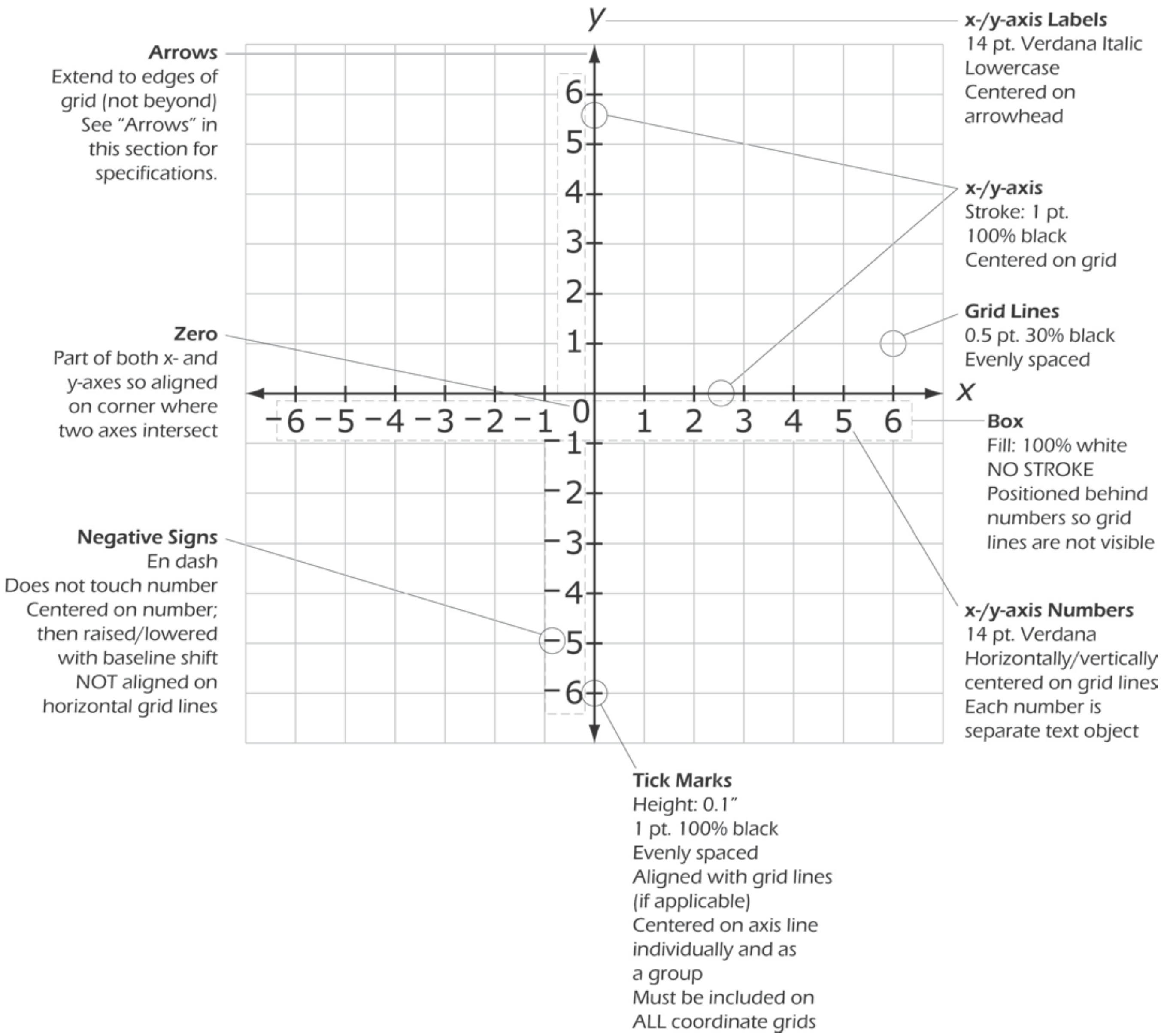
Note: People and animals should NOT be represented as half symbols in pictographs.

Tally Charts

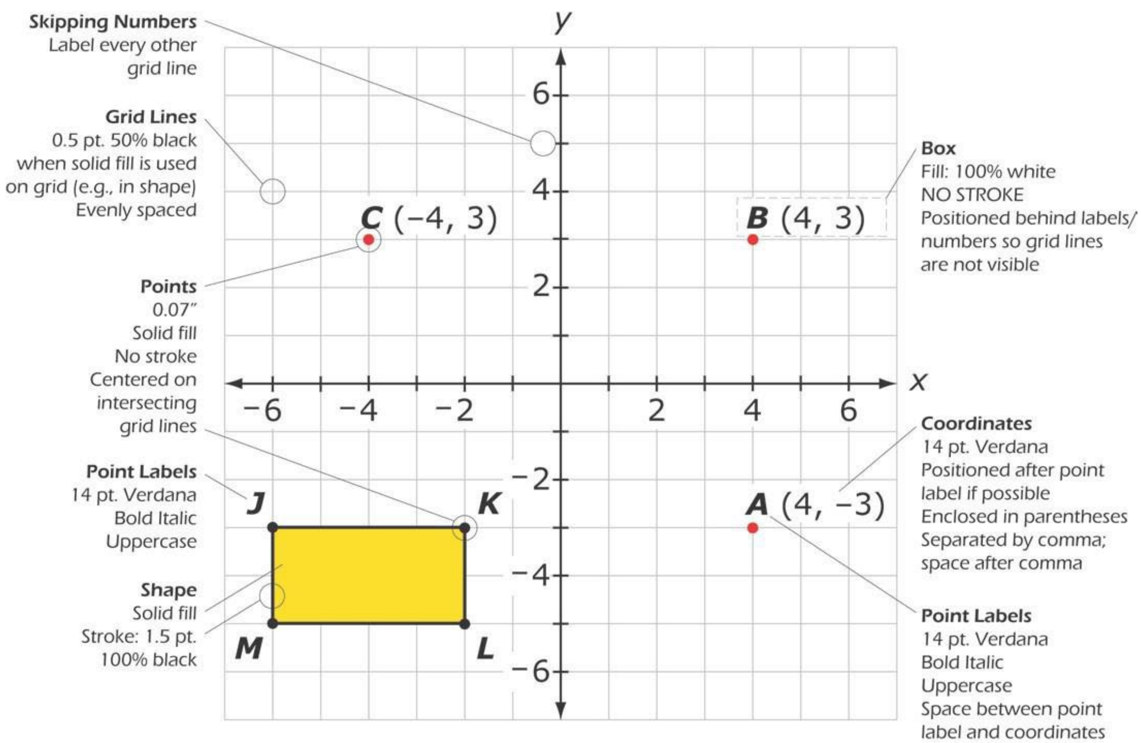


H. Coordinate Grids

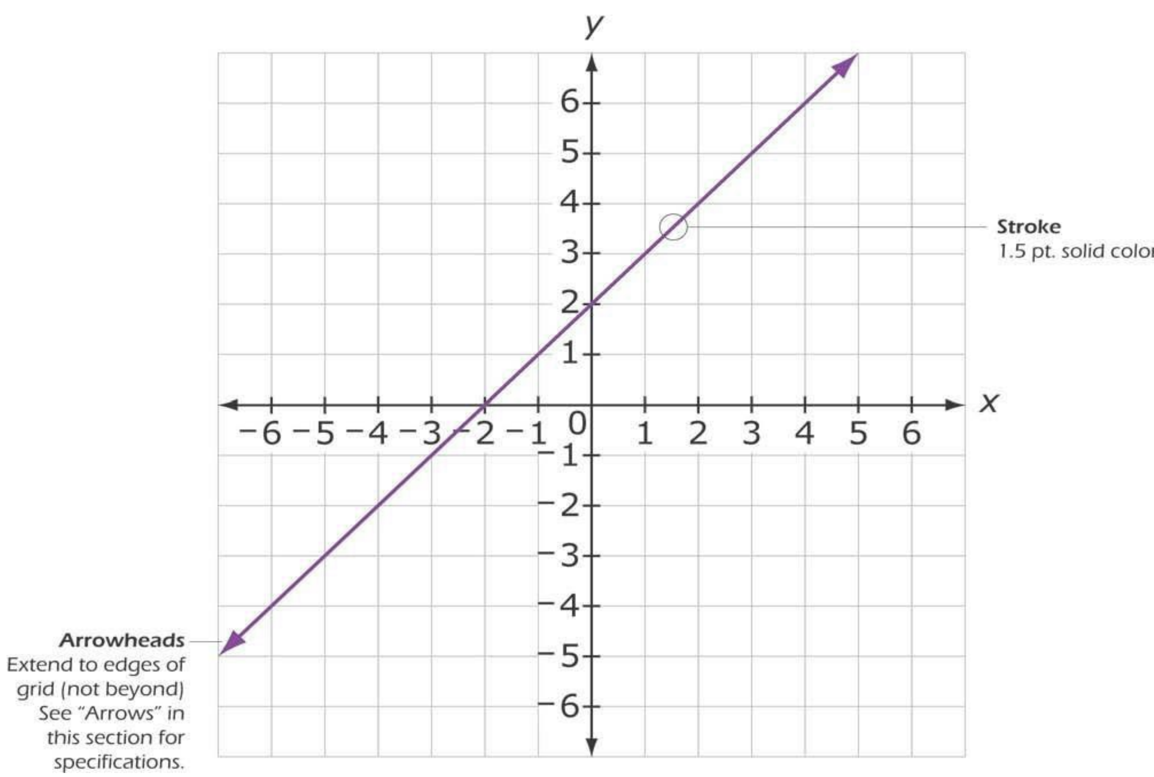
The diagrams in this section provide specifications for coordinate grids, including coordinate grids with plotted points, lines, and shapes.



Plotted Points and Shapes



Plotted Lines

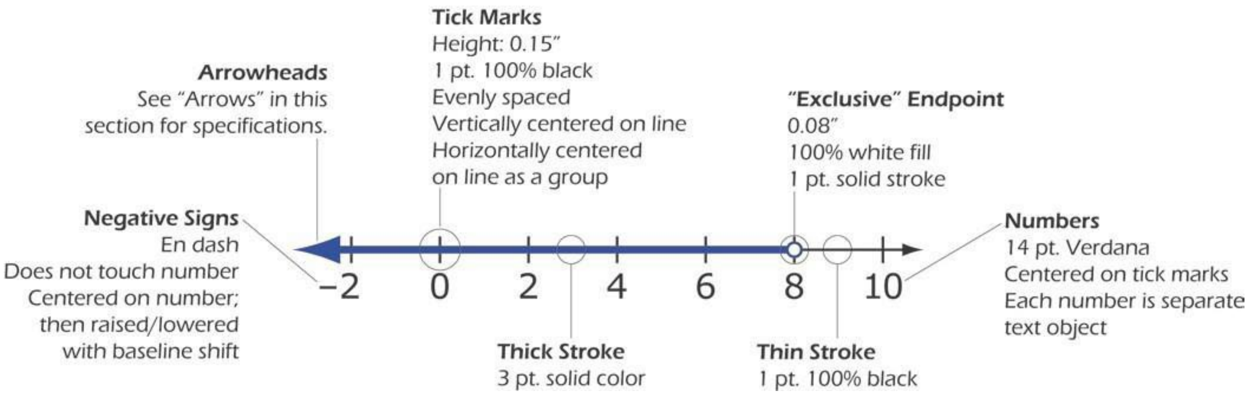


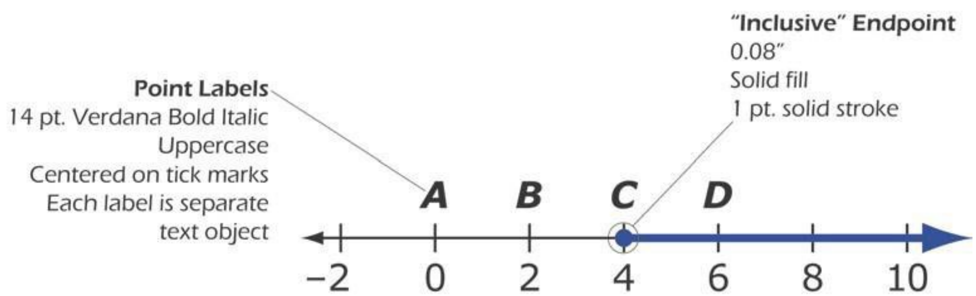
Note: Use graphing software to ensure that lines are accurately plotted on coordinate grids.

I. Other Types of Graphics

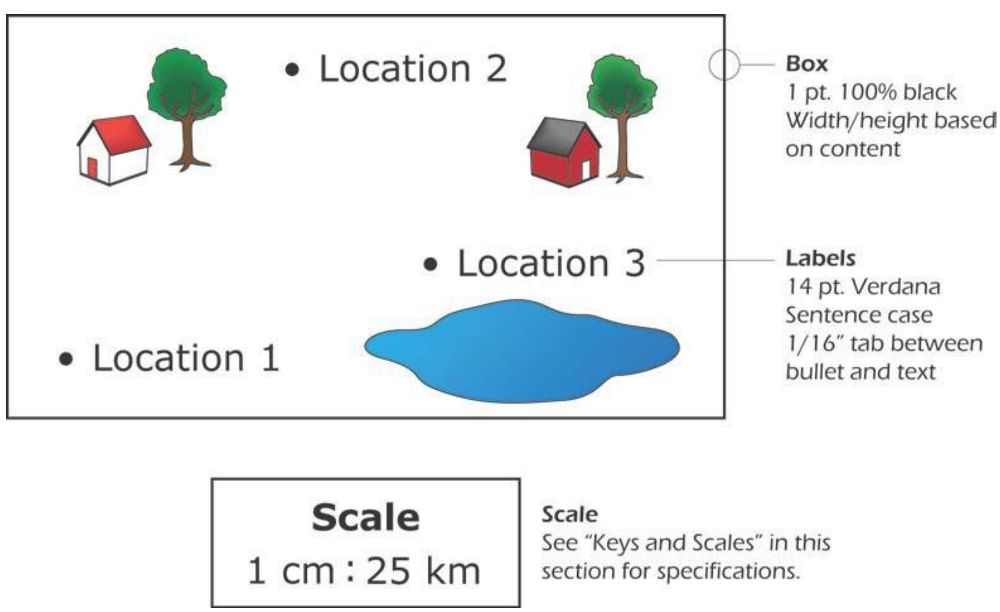
The diagrams in this section show specifications for miscellaneous graphics, including number lines, box-and-whisker plots, line plots, stem-and-leaf plots, spinners, maps, and graphic organizers.

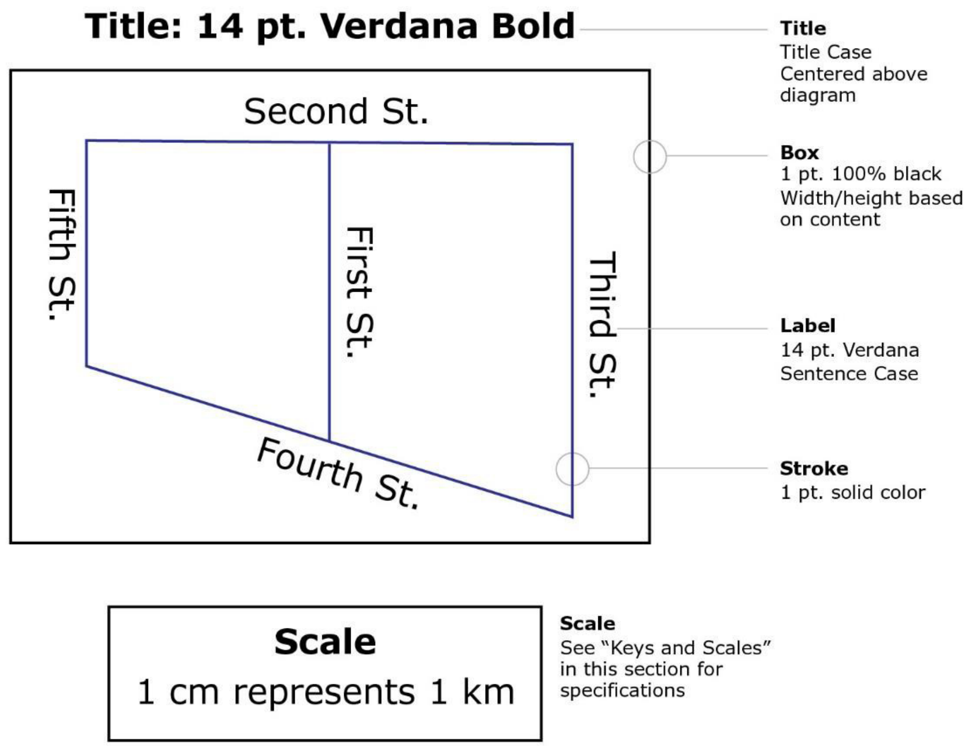
Number Lines





Maps




Title: 14 pt. Verdana Bold
Title
Title Case
Centered above diagram
Second St.
Fifth St.
First St.
Third St.
Fourth St.
Box
1 pt. 100% black
Width/height based on content
Label
14 pt. Verdana
Sentence Case
Stroke
1 pt. solid color
Scale
1 cm represents 1 km
Scale
See "Keys and Scales" in this section for specifications

J. Animations

- Graphics for animations and simulations follow three-dimensional science graphics style guidelines.
    - Animation art style should not be different from those produced for APG static images.
- Dimensions for animations and simulations:
    - In a stimulus: animation can be no wider than 350 pixels to eliminate horizontal scrolling.
    - In a simulation: dimensions are predetermined by the item layout.
- Animations, graphics, and simulations must have file sizes that keep the entire item or cluster's file size under 500 kb.
- Animations and simulations should be short and succinct as to reduce the amount of test time spent running them.
- For animations (not simulations), include the directive "Click on the small gray arrow to start the animation …" OR "Click on the small gray arrow to watch [Earth revolve around the sun, the rabbit come out of its hole, etc.]."

Appendix A: Word List

Word List

This appendix provides guidelines for the capitalization, hyphenation, and spelling of terms. See "Compound Terms" in Part I for additional guidelines.

A
AD (uppercase; precedes date)

a.m. (lowercase)

B
BC/BCE (uppercase; follows date)

big bang theory (lowercase)

C
criterion (singular), criteria (plural)

cutout (n, adj), cut out (v)

D
data are (plural)

E
Earth, in reference to the planet (not used with the article the)

earth, in reference to earth material (used with the article the)

eastern hemisphere (lowercase)

equator (lowercase)

F
fall (season)

Force is greater, not larger: According to Sir Isaac Newton's Law of Universal Gravitation, all objects that have mass are attracted to each other. Mass is the measure of an object's matter (what it's made up of). The greater an object's mass, the greater its gravitational force.

flowchart (per Webster's)

fresh water (n), freshwater (adj)

full-size (adj)

H
the Hawaiian Islands, but the island of Hawaii

high-pressure (adj), high pressure (n)

K
kinetic energy (KE)

L
landfall

Law – uppercase in terms like “Newton’s First Law” or “Coloumb’s Law”

life cycle

life-span

lightbulb

M
moon

N
northern hemisphere (lowercase)

P
potential energy (PE)

R
rain forest (n)

round-trip (n, adj)

S
salt water (n), saltwater (adj)

setup (n), set up (v)

solar system

southern hemisphere (lowercase)

spring (season)

summer

sun

T

tide pool

tidewater

timeline

U

underwater (adj, adv)

W

western hemisphere (lowercase)

Appendix B: Resources, Research, and Bibliography

Recommended Resources

The style conventions and specifications in this document are based largely on information from the sources listed in this section. Refer to these sources for additional information.

Chicago Manual of Style and Words into Type
First published in 1906, the Chicago Manual of Style (CMOS) is one of the oldest and most comprehensive editorial style guides available. The sixteenth edition, published in 2010, was updated in consultation with a broad range of scholars and professionals in the fields of academics and publishing.

Different style guides have different uses. For example, the Associated Press Stylebook is used primarily by journalists, the Publication Manual of the American Psychological Association is used for social science publications, and the MLA Handbook for Writers of Research Papers is most commonly used by writers of research papers in the humanities. CMOS is widely used in educational, scholarly, and trade publishing, as is Words into Type, another well-respected general-purpose style manual. Both CMOS and Words into Type provide broader coverage of mechanical issues, grammar, and usage than the more specialized style manuals listed above.

Merriam-Webster’s Collegiate Dictionary
Because hundreds of new words are added to the English language each year, and preferences regarding issues such as spelling and hyphenation change over time, it’s important that publishing professionals use a recent edition of a good dictionary. Merriam-Webster’s Collegiate Dictionary is not only one of the most popular dictionaries on the market (as the best-selling dictionary in the United States) but is also recommended by CMOS and used by many educational and academic publishers.

Garner’s Modern American Usage
Bryan A. Garner wrote the grammar-and-usage chapter of CMOS, and his usage book is an appropriate companion to CMOS, significantly expanding on the usage guidelines provided in chapter 5 of CMOS. Garner’s Modern American Usage is considered one of the best books available on contemporary usage. Garner takes a prescriptive approach, which means that his usage guidelines are based on established norms and rules for the way language should be used.

The Copyeditor’s Handbook: A Guide for Book Publishing and Corporate Communications
Amy Einsohn, the author of The Copyeditor’s Handbook, has twenty years of experience as a professional editor and teacher of copyediting classes and is highly regarded in the copyediting community. Her book, which addresses the ABCs of copyediting, editorial style, and language editing, is intended to be used as a tool for self-instruction or a textbook for copyediting classes. The Copyeditor’s Handbook has been recommended by current and former editors at CMOS, including Carol Fisher Saller and Margaret Mahan.

Support for Selected Style Preferences

Emphasis Terms

The treatment of various elements of style, including emphasis terms, varies according to the preferences of the user, but it is recommended that emphasis terms in test items be set in boldface. The publication Considerations for the Development and Review of Universally Designed Assessments[1] cites the following arguments for and against the various treatment options for emphasis text:

- Standard typeface, uppercase and lowercase, is more readable than italic, slanted, small caps, or all caps (Tinker, 1963).
- Text printed completely in capital letters is less legible than text printed completely in lowercase, or normal mixed-case text (Carter, Dey, and Meggs, 1985).
- Italic is far less legible and is read considerably more slowly than regular lowercase (Worden, 1991).
- Boldface is more visible than lowercase if a change from the norm is needed (Hartley, 1985).

Ten style guides from Smarter Balanced states and the consortium were evaluated. Seven of the ten recommended the use of boldface for emphasis terms, whereas one recommended underscoring, another recommended small caps, and the last did not specify. Designers of online content agree that "[o]n the Web, the most common and effective method [for emphasizing text] is the use of a bold face from the current font family."[2]

In addition, the application of a particular treatment to a style element could prove confusing if repeated to represent another style element: In the Smarter Balanced Style Guide, underscoring is used to designate vocabulary terms. That, combined with the fact that the use of two treatment styles for a single element can appear overpowering, reinforces the recommendation that boldface alone be used for emphasis terms. This recommendation is also supported by the Test Accessibility and Modification Inventory (TAMI).[3]

Exponents and Superscript

These elements should be smaller than running text and should not be separated from the preceding text by a space. It is recommended that exponents and superscript characters be smaller than running text (scaled to 70% of base print size). Increasing the size of running text around such characters is not feasible, and increasing the size of the characters themselves introduces a risk that students will misinterpret the characters as running text and not as exponents or superscripts.

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1 Thompson, S. J., Johnstone, C. J., Anderson, M. E., and Miller, N. A. (2005, November). Considerations for the Development and Review of Universally Designed Assessments (Center on Educational Outcomes Tech. Rep. 42). Retrieved February 6, 2012, from www.cehd.umn.edu/nceo/OnlinePubs/Technical42.htm

2 Hume, A. (2005, December). The Anatomy of Web Fonts. Retrieved February 13, 2012, from //www.sitepoint.com/anatomy<web<fonts

3 Beddow, P. A. (2009). Test Accessibility and Modification Inventory: Quantifying and Improving the Accessibility of Tests and Test Items. Presented at the CCSSO 2009 National Conference on Student Assessment. Retrieved February 6, 2012, from http://peabody.vanderbilt. edu/Documents/pdf/PRO/TAMI_CCSSO_Beddow.pdf

The general accessibility guidelines include discussion of magnification tools. In addition, the accessibility spoken/audio business rules provide guidelines on how mathematical notation is to be presented in spoken form. The magnification tools and spoken support should allow students with visual impairment to access all the information available on screen.

In regard to ordinals, it is recommended to use 1st, 2nd, 3rd, etc., rather than 1^{st}, 2^{nd}, 3^{rd}. In this way, the exponent size consideration is avoided, and ordinals are as easily read as other running text on a page.

Typeface: Verdana

It is recommended to use Verdana for onscreen testing materials, for its readability as compared to Times New Roman and Arial. Although other fonts are available that are specially designed to further enhance readability, these custom fonts may not be as widely available on student computers and may require the test delivery system to supply the font as part of system installation.

Serif fonts (e.g., Times New Roman), which are popular in print, can appear pixilated and blurred onscreen. In contrast, "the straight, low contrast, open strokes of a sans-serif font, such as Verdana, will always leave a good impression on-screen."4 Verdana, which was designed for the screen, offers a generous amount of white space both between and within (glyphs) the characters. Currently, it is the most commonly used font on the Web, owing to its marked legibility on screen.

Preparation of Materials for Persons Who Have Color Vision Deficiencies

Color is one of the most important aspects of visual communication and can be employed to generate interest or to communicate ideas or feelings. Yet colors for an audience with members who have color discrimination problems should be selected carefully to avoid conveyance of unintended meaning. This is especially true in educational and testing materials. Many of these materials rely on good color perception for the interpretation of graphs, charts and illustrations. Yet even the most carefully thought-out graphic may lead the user to an incorrect answer because of poor color selection.

- **Select colors carefully.** Besides black and white, most color blind individuals can only see two colors, blue and caramel (golden brown). Red, yellow, orange, and green take on shades of caramel; purple takes on shades of blue when viewed by a person with colorblindness.

- **Less is more.** Too many colors used thoughtlessly can confuse and negate the message of a graphic. Settle on four or fewer colors and stick with them. Black and white are counted as colors when designing graphics, even though they are not usually considered colors when talking about vision.

- **Use contrasting colors.** Contrast is an important influence on the legibility of graphics, especially for persons with color discrimination problems. Substantial contrast, i.e., the use of dark values with light values, between the color of the foreground and the background should be employed. High contrast makes materials easier to read by both persons with colorblindness and those with typical vision. Light letters on a dark background or dark letters on a light background are most legible, but remember the actual colors of those combinations are important.

Contrasting Colors Appropriate for Persons with Color Perception Difficulties (in order of best contrast value)

- Use black and white.
- Use dark blue and white.
- Use black and bright yellow.
- Use dark blue and bright yellow.
- Use dark brown and white.
- Use pale blue and black.
- Use yellow and purple.

Notice that yellow is recommended as a common color for graphics to be used by persons with poor color discrimination. This is because yellow maintains luminance longer than any other color. Even though it is perceived as a light caramel color by persons with color blindness, it holds its brightness longer than any other hue, and therefore maintains its contrast when paired with a dark color.

Color Combinations to Be Avoided

- Avoid gray with any color, even another value of gray.
- Avoid red with any color except white or blue.
- Avoid green with any color except white.
- Avoid brown with any color except white or blue.
- Avoid purple with any color except yellow or white.
- Avoid orange with any color except blue or white.
- Avoid two values of the same color, such as light blue and dark blue.
- Avoid a neutral color with any other neutral color.

The importance of proper attention to color selection cannot be overlooked when developing tests for individuals or groups that have color vision or color perception deficiencies.

Source:

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[4] Hume, The Anatomy of Web Fonts

Appendix 2-D

Item Review Checklist

Item Review Checklist

Tier 1 – Sufficiency/Appropriateness of the Phenomenon to Assess the Performance Expectation

The elements in this tier are critical. If any of the following conditions are unmet, the item or cluster cannot move forward.

- ☐ Is the phenomenon based on a specific real-world scenario and focused enough to get the student to investigate what the Performance Expectation (PE) intends for them to investigate across **all three dimensions** (i.e., the students' application of the Practice in the context of the Disciplinary Core Idea [DCI] and Crosscutting Concepts [CCC] as intended by the PE is sufficient to make sense of the phenomena)?
- ☐ Is there an appropriate science-related activity that is puzzling and/or intriguing for students to engage in? Is the scenario focused on real-world observations that students can connect with or have direct experience with?
- ☐ Is the context and complexity of the phenomenon grade-appropriate?
- ☐ Cluster Task Statement: Does the "call to action" reflect the end goal of the interactions to be answered? Does the statement make sense? Is this an engaging and reasonable outcome to work towards?
- ☐ Is the phenomenon presented in way(s) that all students can access and comprehend it based on information provided (including text, graphics, data, images, animations, etc.)? Is the phenomenon free of cultural bias, insensitivity or depreciation of unsafe situations?

Tier 2 – Review of Specific Elements by Component

Stimulus

Reading Load/Readability/Style

- ☐ Is the reading load appropriate for the grade (i.e., the amount of text minimized to reduce cognitive load)?
- ☐ Is the language and vocabulary appropriate for the grade?
- ☐ Non-specific vocabulary should be one grade level lower than the tested grade.
- ☐ Science vocabulary should be part of the "Science Vocabulary Students Are Expected to Know" in the item specifications.
- ☐ Is all of the information in the stimulus necessary for the student to complete the item interactions?
- ☐ Is language consistent throughout the cluster (i.e., does not switch between steam and vapor)?

- ☐ Is everything in the active voice (i.e., avoids unnecessary and unclear passive construction)?

Measurement/Units

- ☐ Are the data in SI units? Check style guide for exceptions.
- ☐ Are units of measurement introduced or defined before they are used in graphs/tables?
- ☐ Are the dependent/independent variables on the correct axes or in the correct columns?
- ☐ Are the graphs/tables/pictures free of extraneous information and appropriate for the grade level?
- ☐ Is there information included in graphs/pictures/tables that is not necessary and can be removed?
- ☐ Do the graphs/tables/pictures depend on color? Is there another way to represent the difference in the data other than by color (e.g., using patterns)?

Data Source and Scientific Reference

- ☐ Is content both accurate and appropriate in its context?
- ☐ Are the data sources appropriate for the subject/grade and taken from reliable academic sources?
- ☐ Does the item use the most up-to-date explanation?

Formatting

- ☐ Is everything presented within the browser dimensions (1024x768) without horizontal scrolling?
- ☐ Are the tables/graphs/etc. laid out in a way that is easy to read?
- ☐ Are details and text in animations easy to see? Are labels in diagrams easy to read?
- ☐ Is the average file size appropriate for test delivery (approximately 100KB, 250KB maximum)?

Item

Interaction and Alignment to Specifications

- ☐ Does the item make sense if you are responding to the interactions as if you are the student in the intended grade-level?
- ☐ Does the interaction require the student to demonstrate the science practice and/or content that the PE is assessing them on?
- ☐ Are the interactions grade level/developmentally appropriate and do they follow a logical progression? Do the interactions use appropriate scaffolding to guide students in making sense of the phenomena?
- ☐ Do the interactions align with the task demands?

- Do the interactions avoid redundancy? Do the student interactions follow a coherent progression?
- Do the student interactions follow a coherent progression? Does the order of the interactions allow students to make sense of the phenomenon or problem?
- Is the item stem worded in a way that makes the intent of the interaction clear to the student?
- Is it clear to the student what they will be scored on in the interaction?
- Is the language (e.g., words, phrases) consistent throughout the stimulus and items?

Grade Appropriate

- Is the content within the item accurate and grade appropriate?
- Are the correct units used? Are the units grade appropriate? Where necessary, are the abbreviations of the units introduced?
- Is the number of item parts/scoring assertions appropriate for the grade level?
- Is the mathematics level appropriate for the grade being tested?

Formatting

- Is everything presented within the browser frame without horizontal scrolling?
- Are the tables/graphs/etc. easy to read? Are the images created in an appropriate color palette per the Style Guide?
- Are details and text in animations easy to see?

Tier 3 – Review of the Scoring and Assertion(s)

Scoring Accuracy

- Do the interactions/task provide clear guidance on how student responses will be scored/interpreted?
- Are scores assigned appropriately as correct or incorrect?
- Are the dependencies logical?
- Are any of the scoring assertions exclusive (i.e., the student can get only one assertion correct and not another at any given time)?
- Is the correct answer clear and distinct from the distractors?
- Does the scoring result in an appropriate distribution of points?

Scoring Assertions

- ☐ Is the appropriate wording used for each scoring assertion (e.g., <What the student did as a response> provides evidence of an understanding of/ability to <inference about student's ability relative to the PE being measured>)?
- ☐ Does the inference follow from the data?
- ☐ Are the assertions specific to the individual interactions (i.e., does not just repeat the PE)?
- ☐ Are the scoring assertions in the same order as the interactions?
- ☐ Does the wording of the scoring assertion make it very clear which interaction and action it refers to?

Strategies for Editing Text to Produce Plain Language

- Reduce excessive length
- Use common words
- Avoid ambiguous words
- Limit irregularly spelled words
- Avoid inconsistent naming and graphic conventions
- Avoid multiple terms for the same concept
- Limit the use of embedded clauses and phrases
- Avoid the passive voice

Appendix 2-E

Content Advisory Committee Participant Details

Content Advisory Committee Participant Details

Table E-1. Content Advisory Committee Participants, Science

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
Connecticut	February ‘17	Cromwell, CT	41	**Gender:** 78% Female, 22% Male	45	31
	May ‘17	New Britain, CT	42	**Gender:** 74% Female, 26% Male	40	38
	October ‘17	New Britain, CT	41	**Gender:** 80% Female, 20% Male	75	64
	November ‘17	New Britain, CT	35	**Gender:** 83% Female, 17% Male	41	32
	January/ February ‘18	New Britain, CT	33	**Gender:** 82% Female, 18% Male	42	25
	October ‘18	New Britain, CT	45	**Gender:** 84% Female, 16% Male	84	54
	November ‘18	New Britain, CT	49	**Gender:** 86% Female, 14% Male	235	200
	December ‘18	New Britain, CT	32	**Gender:** 81% Female, 19% Male	56	55
	January ‘19	New Britain, CT	44	**Gender:** 82% Female, 18% Male	65	59
	September ‘19	Rocky Hill, CT	50	**Gender:** 82% Female, 18% Male	60	57
	November ‘19	Cromwell, CT	44	**Gender:** 80% Female, 20% Male **Ethnicity:** 5% Hispanic or Latino, 93% White or Caucasian, 2% Preferred Not to Answer **Region:** 14% Rural, 59% Suburban, 16% Urban, 11% Not Applicable **Teaching Experience:** 2% None, 9% 1 to 5 years, 9% 6 to 10 years, 30% 11 to 15 years, 25% 16 to 20 years, 25% More than 20 years	171	153
	January ‘20	Cromwell, CT	57	**Gender:** 75% Female, 25% Male **Ethnicity:** 5% Black or African American, 2% Franco-American, 5% Hispanic or Latino, 88% White or Caucasian **Region:** 14% Rural, 63% Suburban, 19% Urban, 4% Not Applicable	190	161

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Teaching Experience: 12% 1 to 5 years, 14% 6 to 10 years, 25% 11 to 15 years, 21% 16 to 20 years, 28% More than 20 years		
	July ‘20[a]	Virtual	23	**Gender:** 83% Female, 17% Male **Ethnicity:** 4% Black or African American, 91% White or Caucasian, 4% Prefer Not to Answer	48	44
	July ‘21[a]	Virtual	68	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	26	26
	September ‘21	Virtual	27	**Gender:** 74% Female, 26% Male **Ethnicity:** 4% Black or African American, 96% White or Caucasian **Region:** 41% Suburban, 11% Urban, 7% Not Applicable, 41% Did Not Respond **Teaching Experience:** 7% 1 to 5 years, 15% 6 to 10 years, 15% 11 to 15 years, 15% 16 to 20 years, 48% More than 20 years	149	120
	June/ August ‘22[a]	Virtual	26	**State:** 8% Connecticut, 11% Idaho, 4% North Dakota, 4% Oregon, 19% Rhode Island, 27% Utah, 8% West Virginia, 19% Wyoming **Gender:** 77% Female, 23% Male **Ethnicity:** 15% Hispanic or Latino, 81% White or Caucasian, 4% Race/Ethnicity Not Listed **Region:** 19% Rural, 23% Urban, 31% Suburban, 27% Did Not Respond **Teaching Experience:** 15% 11 to 15 years, 23% 6 to 10 years, 35% 16 to 20 years, 27% More than 20 years	65	63
	July ‘22	Virtual	21	**Gender:** 76% Female, 24% Male **Ethnicity:** 10% Hispanic or Latino, 86% White or Caucasian, 4% Multiracial or Biracial **Region:** 76% Suburban, 10% Urban, 14% Did Not Respond **Teaching Experience:** 19% 6 to 10 years, 4% 11 to 15 years, 10% 16 to 20 years, 67% More than 20 years	62	56

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
Hawaii	July ‘17	Honolulu, HI	22	**Gender:** 64% Female, 36% Male **Ethnicity:** 5% Black or African American, 5% Chinese and White, 9% Filipino, 14% Hawaiian, 9% Hispanic or Latino, 14% Japanese, 41% White or Caucasian, 5% Did Not Respond **Teaching Experience:** 64% General Education, 5% General Education with SPED Certification, 5% SPED Teacher, 23% Other, 5% Did Not Respond	25	[b]
	September ‘17	Honolulu, HI	20	**Gender:** 75% Female, 25% Male **Ethnicity:** 5% Black or African American, 10% Filipino, 10% Hispanic or Latino, 15% Japanese, 50% White or Caucasian, 10% Did Not Respond **Teaching Experience:** 65% General Education, 15% General Education with SPED Certification, 20% Other	65	[b]
	October ‘18	Honolulu, HI	28	**Gender:** 83% Female, 17% Male **Ethnicity:** 31% Asian, 7% Asian Pacific Islander, 3% Hawaiian, 10% Hispanic or Latino, 28% White or Caucasian, 10% Two or More, 10% Did Not Respond **Teaching Experience:** 83% General Education, 24% Other	85	79
	February/ March ‘19	Honolulu, HI	21	**Gender:** 80% Female, 20% Male **Ethnicity:** 50% Asian, 35% White or Caucasian, 15% Two or More **Teaching Experience:** 65% General Education, 5% General Education with SPED Certification, 5% SPED Teacher, 25% Other	44	44
	June/ July ‘20	Virtual	17	**Gender:** 18% Female, 12% Male, 70% Did Not Respond **Ethnicity**: 6% Asian or Pacific Islander, 6% Multiracial or Biracial, 18% White or Caucasian, 70% Did Not Respond **Region:** 12% Rural, 12% Suburban, 76% Did Not Respond **Teaching Experience:** 6% 6 to 10 years, 12% 11 to 15 years, 12% More than 20 years, 70% Did Not Respond	344	324
	July ‘20[a]	Virtual	28	**State:** 14% Connecticut, 4% Hawaii, 14% Idaho, 14% Montana, 7% Oregon, 4% Rhode Island, 4% Utah, 7% Vermont, 11% West Virginia, 7% Wyoming, 14% Did Not Respond **Gender:** 86% Female, 14% Male	90	90

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Ethnicity: 4% Black or African American, 46% White or Caucasian, 50% Did Not Respond **Region:** 7% Rural, 14% Suburban, 14% Urban, 64% Did Not Respond **Teaching Experience:** 3% 6 to 10 years, 11% 11 to 15 years, 14% 16 to 20 years, 18% More than 20 years, 54% Did Not Respond		
	June/ August '22[a]	Virtual	25	**State:** 12% Connecticut, 16% Idaho, 16% North Dakota, 16% Oregon, 20% Rhode Island, 12% Utah, 4% West Virginia, 4% Wyoming **Gender:** 88% Female, 12% Male **Ethnicity:** 8% Hispanic or Latino, 4% Multiracial or Biracial, 80% White or Caucasian, 8% Did Not Respond **Region:** 20% Rural, 16% Suburban, 12% Urban, 52% Did Not Respond **Teaching Experience:** 4% 1 to 5 Years, 32% 6 to 10 Years, 20% 11 to 15 Years, 20% 16 to 20 Years, 16% More than 20 Years, 8% Did Not Respond	46	46
	July '22	Honolulu, HI	9	**Gender:** 67% Female, 22% Male, 11% Non-Binary **Ethnicity:** 44% Asian/Pacific Islander, 11% Hispanic or Latino, 11% Multiracial or Biracial, 22% White or Caucasian, 11% Did Not Respond **Region:** 11% Hilo, 11% Maui, 78% Oahu **Teaching Experience:** 11% 1 to 5 years, 11% 6 to 10 years, 11% 11 to 15 years, 22% 16 to 20 years, 44% More than 20 years	45	44
	July '22	Honolulu, HI	9	**Gender:** 67% Female, 22% Male, 11% Non-Binary **Ethnicity:** 44% Asian/Pacific Islander, 11% Hispanic or Latino, 11% Multiracial or Biracial, 22% White or Caucasian, 11% Did Not Respond **Region:** 11% Hilo, 11% Maui, 78% Oahu **Teaching Experience:** 11% 1 to 5 years, 11% 6 to 10 years, 11% 11 to 15 years, 22% 16 to 20 years, 44% More than 20 years	306	306
ICCR	March '18	Virtual	38	**State:** 45% Connecticut, 5% Hawaii, 3% Indiana, 3% Maryland, 8% Oregon, 8% Utah, 26% West Virginia, 3% Wyoming **Gender:** 74% Female, 26% Male	152	[b]

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
	July ‘20[a]	Virtual	6	**State:** 17% Connecticut, 17% Idaho, 17% Oregon, 17% Rhode Island, 33% Did Not Respond **Gender:** 83% Female, 17% Male **Ethnicity**: 33% White or Caucasian, 67% Did Not Respond **Region:** 17% Suburban, 83% Did Not Respond **Teaching Experience:** 33% 16 to 20 years, 67% Did Not Respond	57	56
	July ‘21[a]	Virtual	68	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	141	141
	July ‘21	Virtual	45	**State:** 33% Connecticut, 9% Hawaii, 4% Idaho, 2% Montana, 7% North Dakota, 4% Oregon, 18% South Dakota, 2% Vermont, 4% West Virginia, 13% Wyoming **Gender:** 80% Female, 18% Male, 2% Did Not Respond **Ethnicity:** 4% Asian or Pacific Islander, 2% Black or African American, 4% Hispanic or Latino, 87% White or Caucasian, 2% Did Not Respond **Region:** 36% Rural, 24% Suburban, 20% Urban, 20% Did Not Respond **Teaching Experience:** 2% None, 2% Less than 1 year, 11% 1 to 5 years, 33% 6 to 10 years, 16% 11 to 15 years, 9% 16 to 20 years, 24% More than 20 years, 2% Did Not Respond	163	158
	June/ August ‘22[a]	Virtual	12	**State:** 17% Connecticut, 17% Idaho, 58% North Dakota, 8% Oregon **Gender:** 92% Female, 8% Male **Ethnicity:** 67% White or Caucasian, 33% Did Not Respond **Region:** 33% Suburban, 33% Urban, 33% Did Not Respond **Teaching Experience:** 17% 6 to 10 Years, 42% 11 to 15 Years, 8% More than 20 Years, 33% Did Not Respond	121	118
Idaho	December ‘18	Boise, ID	21	Not Collected	241	230
	October ‘19	Boise, ID	18	**Gender:** 83% Female, 11% Male, 6% Did Not Respond **Ethnicity:** 100% White or Caucasian	231	211

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Region: 50% Rural, 17% Suburban, 22% Urban, 11% Not Applicable **Teaching Experience:** 11% 1 to 5 years, 22% 6 to 10 years, 17% 11 to 15 years, 11% 16 to 20 years, 28% 21 or more years, 11% Did Not Respond		
	July ‘20[a]	Virtual	2	**State:** 100% Hawaii **Gender:** 100% Female	12	12
	October ‘20	Virtual	[c]	Not Collected	14	14
	July ‘21[a]	Virtual	8	**Gender:** 88% Female, 13% Male **Ethnicity:** 100% White or Caucasian **Region:** 25% Rural, 25% Suburban, 50% Did Not Respond **Teaching Experience:** 38% 6 to 10 years, 38% 11 to 15 years, 13% 16 to 20 years, 13% More than 20 years	[b]	[b]
	November ‘21	Virtual	11	**Gender:** 91% Female, 9% Male **Ethnicity**: 73% White or Caucasian, 17% Did Not Respond **Region:** 18% Rural, 18% Suburban, 64% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 46% 6 to 10 years, 9% 11 to 15 years, 9% More than 20 years, 27% Did Not Respond	317	286
	June/ August ‘22[a]	Virtual	14	**State:** 29% Connecticut, 14% Oregon, 7% Rhode Island, 7% North Dakota, 21% Utah, 7% West Virginia, 14% Wyoming **Gender:** 71% Female, 29% Male **Ethnicity:** 7% Hispanic or Latino, 93% White or Caucasian, **Region:** 36% Rural, 21% Suburban, 14% Urban, 29% Did Not Respond **Teaching Experience:** 29% 6 to 10 Years, 21% 11 to 15 Years, 29% 16 to 20 Years, 21% More than 20 Years	12	12
	July ‘22	Virtual	5	**Gender**: 100% Female **Ethnicity**: 80% White or Caucasian, 20% Did Not Respond **Region:** 20% Rural, 40% Suburban, 40% Did Not Respond **Teaching Experience**: 40% 1 to 5 years, 40% 6 to 10 years, 20% 11 to 15 years	244	204
Montana	January ‘20	Helena, MT	15	Not Collected	149	139
	July ‘20[a]	Virtual	4	**State:** 25% Hawaii, 25% Idaho, 25% Oregon, 25% Rhode Island **Gender:** 75% Female, 25% Male	9	9

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Ethnicity: 50% White or Caucasian, 50% Did Not Respond **Region:** 50% Urban, 50% Did Not Respond **Teaching Experience:** 50% More than 20 years, 50% Did Not Respond		
	October '20	Virtual	8	**Gender:** 13% Female, 88% Did Not Respond **Ethnicity**:13% White or Caucasian, 88% Did Not Respond **Region:** 13% Rural, 88% Did Not Respond **Teaching Experience:** 13% 16 to 20 years, 88% Did Not Respond	156	140
	July '21[a]	Virtual	68	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	36	36
	October '21	Virtual	6	**Gender:** 83% Female, 17% Did Not Respond **Ethnicity**: 17% Hispanic or Latino, 67% White or Caucasian, 17% Did Not Respond **Region:** 67% Rural, 33% Did Not Respond **Teaching Experience:** 33% 6 to 10 years, 33% 11 to 15 years, 17% More than 20 years, 17% Did Not Respond	41	39
	June/ August '22[a]	Virtual	9	**State:** 22% Connecticut, 22% Idaho, 11% Oregon, 11% Rhode Island, 11% West Virginia, 22% Wyoming **Gender:** 78% Female, 22% Male **Ethnicity:** 100% White or Caucasian **Region:** 33% Rural, 22% Suburban, 11% Urban, 33% Did Not Respond **Teaching Experience:** 22% 6 to 10 Years, 33% 11 to 15 Years, 11% 16 to 20 Years, 33% More than 20 Years	13	13
Multi-State Science Assessment (Rhode Island and Vermont)	January '18	Providence, RI	42	**State:** 90% Rhode Island, 10% Vermont **Teaching Experience:** 69% General Education, 2% Bilingual Education, 14% Science Coordinator, 14% Other	73	58
	March '18	Providence, RI	34	**State:** 25% Rhode Island, 75% Vermont	107	90
	January '19	Concord, NH	21	**Gender:** 74% Female, 26% Male **Teaching Experience:** 69% General Education, 3% Special Education, 29% Other, 6% Not Applicable	116	97

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
	November '19	Fairlee, VT	17	**State:** 29% Rhode Island, 6% Vermont, 65% Did Not Respond **Gender:** 23% Female, 12% Male, 65% Did Not Respond **Ethnicity**: 35% White or Caucasian, 65% Did Not Respond **Region:** 6% Rural, 17% Suburban, 77% Did Not Respond **Teaching Experience:** 6% 11 to 15 years, 17% 16 to 20 years, 12% More than 20 years, 65% Did Not Respond	136	118
	July '20[a]	Virtual	8	**State:** 13% Connecticut, 13% Hawaii, 13% Montana, 13% Oregon, 25% Oregon, 25% Did Not Respond **Gender:** 88% Female, 13% Male **Ethnicity**: 38% White or Caucasian, 63% Did Not Respond **Region:** 13% Suburban, 88% Did Not Respond **Teaching Experience:** 13% 6 to 10 years, 13% 11 to 15 years, 13% More than 20 years, 63% Did Not Respond	27	27
	July '21[a]	Virtual	68	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	32	31
	August '21	Virtual	11	**State:** 45% Rhode Island, 55% Vermont **Gender:** 73% Female, 27% Male **Ethnicity:** 100% White or Caucasian **Region:** 36% Rural, 18% Suburban, 9% Urban, 36% Did Not Respond **Teaching Experience:** 27% 6 to 10 years, 18% 11 to 15 years, 27% 16 to 20 years, 27% More than 20 years	93	91
Oregon	August '17	Salem, OR	10	**Gender:** 90% Female, 10% Male **Region:** 50% Rural, 50% Urban **Teaching Experience:** 100% General Education, 10% Bilingual Education, 10% Special Education, 20% Administration	235	142
	August '18	Salem, OR	20	**Gender:** 80% Female, 20% Male **Ethnicity:** 95% White or Caucasian, 5% Other **Region:** 44% Rural, 56% Urban	257	200

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Teaching Experience: 65% Bilingual Education, 65% Special Education, 55% Other		
	October ‘18	Salem, OR	11	**Gender:** 100% Female **Ethnicity:** 91% White or Caucasian, 9% Other **Region:** 45% Rural, 55% Urban **Teaching Experience:** 18% General Education, 91% Bilingual Education, 45% Special Education, 55% Other	60	30
	December ‘18	Virtual	16	**Gender:** 63% Female, 38% Male **Ethnicity:** 6% Asian, 94% White or Caucasian **Region:** 50% Suburban, 50% Urban **Teaching Experience:** 38% General Education, 63% Bilingual Education, 25% Special Education	62	48
	October ‘19	Salem, OR	17	**Gender:** 76% Female, 24% Male **Ethnicity:** 6% Asian, 88% White or Caucasian, 6% Other **Region:** 29% Rural, 71% Urban **Teaching Experience:** 82% General Education, 29% Bilingual Education, 18% Special Education	255	221
	July ‘20[a]	Virtual	9	**State:** 22% Idaho, 11% Vermont, 22% West Virginia, 11% Wyoming, 33% Did Not Respond **Gender:** 78% Female, 22% Male **Ethnicity**: 44% White or Caucasian, 56% Did Not Respond **Region:** 11% Rural, 11% Suburban, 78% Did Not Respond **Teaching Experience:** 11% 11 to 15 years, 11% 16 to 20 years, 22% More than 20 years, 56% Did Not Respond	22	20
	August ‘20	Virtual	21	**Gender:** 71% Female, 29% Male **Ethnicity:** 90% White or Caucasian, 5% Hispanic or Latino, 5% Native American **Region:** 5% Urban, 43% Suburban, 52% Rural **Teaching Experience:** 86% General Education, 81% Bilingual Education, 81% Special Education, 14% Administration, 5% Other	159	134
	August ‘21	Virtual	14	**Gender:** 86% Female, 14% Male **Ethnicity:** 86% White or Caucasian, 7% Asian and/or Pacific Islander, 7% Hispanic or Latino **Region:** 14% Urban, 72% Suburban, 14% Rural **Teaching Experience:** 64% General Education, 7% Bilingual Education, 7% Special Education, 22% Other	375	308

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
	July ‘22	Virtual	14	**Gender:** 64% Female. 36% Male **Ethnicity:** 100% White or Caucasian **Region:** 36% Rural, 28% Suburban, 36% Urban **Teaching Experience:** 7% 1 to 5 years, 36% 6 to 10 years, 21% 11 to 15 years, 7% 16 to 20 years, 29% More than 20 years	66	58
Rhode Island	October ‘22	Virtual	20	**Gender:** 85% Female, 15% Male **Ethnicity:** 10% Black or African American, 5% Multiracial or Biracial, 85% White or Caucasian **Region:** 10% Rural, 25% Suburban, 30% Urban, 35% Did Not Respond **Teaching Experience:** 20% 1 to 5 years, 15% 6 to 10 years, 10% 11 to 15 years, 25% 16 to 20 years, 30% More than 20 years	115	93
South Dakota	October ‘19	Pierre, SD	26	**Gender:** 81% Female, 19% Male **Ethnicity:** 4% American Indian or Alaska Native, 4% Asian, 92% White or Caucasian **Region:** 65% Rural, 15% Suburban, 15% Urban, 4% Not Applicable **Teaching Experience:** 12% 1 to 5 years, 12% 6 to 10 years, 19% 11 to 15 years, 19% 16 to 20 years, 38% More than 20 years	235	222
Utah	July ‘17	Park City, UT	18	**Gender:** 74% Female, 26% Male **Ethnicity:** 4% Native American, 91% White or Caucasian, 4% Other **Teaching Experience:** 100% General Education, 4% Special Education, 4% Other	55	51
	December ‘17	Salt Lake City, UT	36	**Gender:** 84% Female, 16% Male **Ethnicity:** 3% American Indian/Alaska Native and White, 94% White or Caucasian, 3% Other **Teaching Experience:** 87% General Education, 10% General Education and Other, 3% General Education and ESOL	64	62
	October ‘19	Provo, UT	16	**Gender:** 25% Female, 75% Did Not Respond **Ethnicity**: 25% White or Caucasian, 75% Did Not Respond **Region:** 25% Suburban, 75% Did Not Respond	91	44

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Teaching Experience: 6% 6 to 10 years, 6% 16 to 20 years, 13% More than 20 years, 75% Did Not Respond		
	July ‘20[a]	Virtual	17	**State:** 6% Connecticut, 12% Hawaii, 18% Idaho, 12% Montana, 12% Oregon, 12% Rhode Island, 6% Vermont, 6% West Virginia, 12% Wyoming, 6% Did Not Respond **Gender:** 82% Female, 18% Male **Ethnicity**: 47% White or Caucasian, 6% Other, 47% Did Not Respond **Region:** 6% Rural, 12% Suburban, 6% Urban, 76% Did Not Respond **Teaching Experience:** 12% 6 to 10 years, 6% 11 to 15, 18% 16 to 20 years, 18% More than 20 years, 47% Did Not Respond	44	44
	July ‘20	Virtual	16	**Gender:** 31% Female, 6% Male, 63% Did Not Respond **Ethnicity**: 6% Asian or Pacific Islander, 19% Hispanic or Latino, 13% White or Caucasian, 63% Did Not Respond **Region:** 19% Urban, 6% Suburban, 75% Did Not Respond **Teaching Experience:** 6% 6 to 10 years, 13% 11 to 15 years, 13% 16 to 20 years, 6% More than 20 years, 63% Did Not Respond	82	76
	December ‘20	Virtual	6	**Gender:** 50% Female, 50% Did Not Respond **Ethnicity**: 17% Hispanic or Latino, 33% White or Caucasian, 50% Did Not Respond **Region:** 17% Suburban, 83% Did Not Respond **Teaching Experience:** 17% 1 to 5 years, 33% 16 to 20 years, 50% Did Not Respond	14	12
	July ‘21[a]	Virtual	68	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	55	53
	August ‘21	Virtual	14	**Gender:** 86% Female, 14% Male **Ethnicity:** 7% Asian or Pacific Islander, 21% Hispanic or Latino, 71% White or Caucasian	62	62

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Region: 14% Rural, 36% Suburban, 43% Urban, 7% Did Not Respond **Teaching Experience:** 7% 1 to 5 years, 21% 6 to 10 years, 21% 11 to 15 years, 29% 16 to 20 years, 21% More than 20 years		
	September ‘22	Salt Lake City, UT	28	**Gender:** 81% Female, 19% Male **Ethnicity:** 2% American Indian or Alaska Native, 1% Asian, 2% Hispanic or Latino, 1% Mediterranean, 80% White or Caucasian **Region:** 26% Rural, 52% Suburban, 16% Urban, 7% Not Applicable **Teaching Experience:** 29% 1 to 5 years, 39% 6 to 10 years, 3% 11 to 15 years, 7% 16 to 20 years, 7% More than 20 years, 16% Not Applicable	111	99
West Virginia	January ‘17	Charleston, WV	28[d]	Not Collected	39	[b]
	October ‘18	Charleston, WV	10	**Gender:** 89% Female, 11% Male **Ethnicity:** 11% Black or African American, 89% White or Caucasian **Region:** 100% Rural **Teaching Experience:** 100% General Education	191	[b]
	January ‘19	Charleston, WV	9	**Gender:** 89% Female, 11% Male **Ethnicity:** 11% Black or African American, 89% White or Caucasian **Region:** 100% Rural	71	67
	July ‘19	Charleston, WV	12	**Gender:** 87% Female, 13% Male **Ethnicity:** 4% Asian, 4% Black or African American, 87% White or Caucasian, 4% Not Applicable **Region:** 70% Rural, 30% Urban, 4% Not Applicable **Teaching Experience:** 72% General Education, 4% Special Education, 13% Other, 13% Not Applicable	50	[b]
	July ‘20[a]	Virtual	8	**State:** 13% Connecticut, 38% Idaho, 13% Oregon, 13% Wyoming, 25% Did Not Respond **Gender:** 100% Female **Ethnicity**: 38% White or Caucasian, 63% Did Not Respond **Region:** 13% Suburban, 13% Rural, 75% Did Not Respond	102	102

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Teaching Experience: 13% 6 to 10 years, 25% More than 20 years, 63% Did Not Respond		
	July ‘21[a]	Virtual	68	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	16	16
	June/ August ‘22[a]	Virtual	8	**State:** 25% Connecticut, 13% Hawaii, 25% Idaho, 13% Rhode Island, 25%Wyoming **Gender:** 88% Female, 12% Male **Ethnicity:** 12% Asian or Pacific Islander, 75% White or Caucasian, 12% Did Not Respond **Region:** 25% Suburban, 12% Urban, 63% Did Not Respond **Teaching Experience:** 12% 6 to 10 years, 38% 11 to 15 years, 25% 16 to 20 years, 12% More than 20 years, 12% Did Not Respond	13	13
Wyoming	December ‘17	Cheyenne, WY	18	Not Collected	32	30
	October ‘18	Cheyenne, WY	19	**Gender:** 79% Female, 21% Male **Teaching Experience:** 5% 3 to 5 years, 21% 6 to 10 years, 42% 11 to 20 years, 32% 21 or more years	39	36
	November ‘19	Cheyenne, WY	22	**Gender:** 91% Female, 9% Male **Teaching Experience:** 9% 3 to 5 years, 23% 6 to 10 years, 18% 11 to 20 years, 50% 21 or more years	44	43
	July ‘20[a]	Virtual	13	**State:** 8% Connecticut, 15% Hawaii, 8% Montana, 15% Oregon, 8% Rhode Island, 23% West Virginia, 23% Did Not Respond **Gender:** 77% Female, 23% Male **Ethnicity**: 8% Asian or Pacific Islander, 23% White or Caucasian, 8% Other, 61% Did Not Respond **Region:** 8% Suburban, 15% Urban, 77% Did Not Respond **Teaching Experience:** 15% 6 to 10 years, 23% 11 to 15 years, 15% 16 to 20 years, 46% Did Not Respond	37	37
	August ‘20	Virtual	14	**Gender:** 29% Female, 7% Male, 64% Did Not Respond **Ethnicity**: 36% White or Caucasian, 64% Did Not Respond **Region:** 22% Rural, 78% Did Not Respond	37	36

State/Item Bank	Date	Location	Number of Committee Members	CAC Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Approved by Committees
				Teaching Experience: 7% 11 to 15 years, 7% 16 to 20 years, 22% More than 20 years, 64% Did Not Respond		
	June/ July '21	Virtual	14	**Gender:** 43% Female, 7% Male, 50% Did Not Respond **Ethnicity:** 50% White or Caucasian, 50% Did Not Respond **Region:** 14% Rural,7% Suburban, 7% Urban, 71% Did Not Respond **Teaching Experience:** 14% 11 to 15 years, 36% More than 20 years, 50% Did Not Respond	39	39
	July '21[a]	Virtual	68	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	39	38
	June/ August '22[a]	Virtual	9	**State:** 22% Connecticut, 22% Idaho, 33% Utah, 22% West Virginia **Gender:** 78% Female, 22% Male **Ethnicity:** 11% Hispanic or Latino, 78% White or Caucasian, 11% Race/Ethnicity Not Listed **Region:** 33% Rural, 11% Suburban, 11% Urban, 44% Did Not Respond **Teaching Experience:** 44% 6 to 10 years, 11% 11 to 15 years, 44% More than 20 years	37	37

[a]Items were reviewed in a combined Content Advisory Committee Meeting that included ICCR and MOU state-owned items. Items reviewed in the combined meetings are displayed by their respective state or bank of ownership.
[b]As of the time of writing this report, the number of science items reviewed and/or approved by Content Advisory Committees is not currently available.
[c]The number of Committee Members is not available at the time of writing this report.
[d]The number of Committee Members includes the total members across ELA, math, and science committees. The specific number of science committee members is currently unavailable.

Appendix 2-F

Fairness Committee Participant Details

Fairness Committee Participant Details

Table F-1. Fairness Committee Participants, Science

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
Connecticut	February ‘17	Cromwell, CT	6	**Gender:** 83% Female, 17% Male	45	1
	December ‘17	New Britain, CT	9	**Gender:** 78% Female, 22% Male	75	[a]
	December ‘17	Cromwell, CT	10	**Gender:** 70% Female, 30% Male	41	[a]
	February ‘18	New Britain, CT	3	**Gender:** 67% Female, 33% Male	42	1
	November ‘18	New Britain, CT	11	**Gender:** 91% Female, 9% Male	319	38
	December ‘18	New Britain, CT	10	**Gender:** 80% Female, 20% Male	56	1
	January ‘19	New Britain, CT	9	**Gender:** 78% Female, 22% Male	65	1
	September ‘19	Cromwell, CT	9	**Gender:** 89% Female, 11% Male	48	0
	November ‘19	Cromwell, CT	10	**Gender:** 80% Female, 20% Male **Ethnicity:** 100% White or Caucasian **Region:** 10% Rural, 70% Suburban, 20% Urban **Teaching Experience:** 10% 6 to 10 years, 20% 11 to 15 years, 10% 16 to 20 years, 60% More than 20 years	52	1
	July ‘20[b]	Virtual	8	**Gender:** 88% Female, 13% Male **Ethnicity:** 13% Hispanic or Latino, 75% White or Caucasian, 13% Prefer Not to Say	43	0
	July ‘21[b]	Virtual	6	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	20	0
	September ‘21	Virtual	7	**Gender:** 43% Female, 57% Male	111	23

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Ethnicity: 100% White or Caucasian **Region:** 29% Suburban, 29% Urban, 43% Did Not Respond **Teaching Experience:** 14% 6 to 10 years, 29% 11 to 15 years, 14% 16 to 20 years, 43% More than 20 years		
	June/ August ‘22[b]	Virtual	3	**State:** 33% Connecticut, 33% Oregon, 33% Wyoming **Gender:** 66% Female, 33% Male **Ethnicity:** 66% White or Caucasian, 33% Did Not Respond **Region:** 66% Suburban, 33% Did Not Respond **Teaching Experience:** 66% More than 20 years, 33% Did Not Respond	65	2
	August ‘22	Virtual	19	**Gender:** 79% Female, 21% Male **Ethnicity:** 5% Hispanic or Latino, 90% White or Caucasian, 5% Multiracial or Biracial **Region:** 63% Suburban, 5% Urban, 32% Not Applicable **Teaching Experience:** 11% 6 to 10 years, 11% 11 to 15 years, 21% 16 to 20 years, 57% More than 20 years	154	27
Hawaii	July ‘17	Honolulu, HI	22	**Gender:** 64% Female, 36% Male **Ethnicity:** 5% Black or African American, 5% Chinese and White, 9% Filipino, 14% Hawaiian, 9% Hispanic or Latino, 14% Japanese, 41% White or Caucasian, 5% Did Not Respond **Teaching Experience:** 64% General Education, 5% General Education with SPED Certification, 5% SPED Teacher, 23% Other, 5% Did Not Respond	25	2
	September ‘17	Honolulu, HI	20	**Gender:** 75% Female, 25% Male **Ethnicity:** 5% Black or African American, 10% Filipino, 10% Hispanic or Latino, 15% Japanese, 50% White or Caucasian, 10% Did Not Respond **Teaching Experience:** 65% General Education, 15% General Education with SPED Certification, 20% Other	65	13
	October ‘18	Honolulu, HI	29	**Gender:** 79% Female, 21% Male **Ethnicity:** 7% Asian, 3% Hawaiian, 7% Asian Pacific Islander, 7% Chinese, 3% Filipino, 10% Hispanic or Latino, 10% Japanese, 28% White or Caucasian, 14% Multi-Racial/Ethnic, 10% Not Applicable	85	6
	February/ March ‘19	Honolulu, HI	21	**Gender:** 80% Female, 20% Male **Ethnicity:** 50% Asian, 35% White or Caucasian, 15% Two or More	44	0

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Teaching Experience: 65% General Education, 5% General Education with SPED Certification, 5% SPED Teacher, 25% Other		
	June/ July '20	Virtual	17	**Gender:** 18% Female, 12% Male, 70% Did Not Respond **Ethnicity**: 18% White or Caucasian, 6% Asian or Pacific Islander, 6% Multiracial or Biracial, 70% Did Not Respond **Region:** 12% Rural, 12% Suburban, 76% Did Not Respond **Teaching Experience:** 6% 6 to 10 years, 12% 11 to 15 years, 12% More than 20 years, 70% Did Not Respond	344	324
	July '20[b]	Virtual	4	**State:** 25% Connecticut, 50% Rhode Island, 25%Utah **Gender:** 100% Female **Ethnicity**: 25% White or Caucasian, 25% Hispanic or Latino, 50% Did Not Respond **Region:** 25% Urban, 75% Did Not Respond **Teaching Experience:** 25% 6 to 10 years, 25% 16 to 20 years, 50% Did Not Respond	55	8
	June/ August '22[b]	Virtual	6	**State:** 33% Oregon, 17% Rhode Island, 33% Utah, 17% West Virginia **Gender:** 67% Female, 33% Male **Ethnicity:** 67% White or Caucasian, 33% Multiracial or Biracial **Region:** 33% Rural, 33% Urban, 33% Did Not Respond **Teaching Experience:** 33% None, 33% 11 to 15 years, 33% More than 20 years	46	0
	July '22	Honolulu, HI	9	**Gender:** 67% Female, 22% Male, 11% Non-Binary **Ethnicity:** 44% Asian/Pacific Islander, 11% Hispanic or Latino, 11% Multiracial or Biracial, 22% White or Caucasian, 11% Did Not Respond **Region:** 11% Hilo, 11% Maui, 78% Oahu **Teaching Experience:** 11% 1 to 5 years, 11% 6 to 10 years, 11% 11 to 15 years, 22% 16 to 20 years, 44% More than 20 years	45	0
	July '22	Honolulu, HI	9	**Gender:** 67% Female, 22% Male, 11% Non-Binary **Ethnicity:** 44% Asian/Pacific Islander, 11% Hispanic or Latino, 11% Multiracial or Biracial, 22% White or Caucasian, 11% Did Not Respond **Region:** 11% Hilo, 11% Maui, 78% Oahu	306	0

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Teaching Experience: 11% 1 to 5 years, 11% 6 to 10 years, 11% 11 to 15 years, 22% 16 to 20 years, 44% More than 20 years		
ICCR	March '18	Virtual	13	**State:** 46% Connecticut, 8% Indiana, 15% Utah, 23% West Virginia, 8% Wyoming **Gender:** 85% Female, 15% Male	152	7
	July '20[b]	Virtual	5	**State:** 20% Connecticut, 40% Rhode Island, 20% Utah, 20% Vermont **Gender:** 100% Female **Ethnicity**: 60% White or Caucasian, 20% Hispanic or Latino, 20% Did Not Respond **Region:** 40% Rural, 20% Suburban, 20% Urban, 20% Did Not Respond **Teaching Experience:** 20% 6 to 10 years, 20% 11 to 15 years, 20% 16 to 20 years, 20% More than 20 years, 20% Did Not Respond	57	0
	July '21[b]	Virtual	15	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond Teaching Experience: 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	157	1
	June/ August '22[b]	Virtual	7	**State:** 71% Connecticut, 14% North Dakota, 14% Utah **Gender:** 100% Female **Ethnicity:** 71% White or Caucasian, 29% Did Not Respond **Region:** 29% Suburban, 71% Did Not Respond **Teaching Experience:** 14% 11 to 15 years, 29% 16 to 20 years, 29% More than 20 years, 29% Did Not Respond	121	3
Idaho	December '18	Boise, ID	15	Not Collected	111	1
	December '21	Boise, ID	21	**Gender:** 81% Female, 19% Male **Ethnicity**: 95% White or Caucasian, 5% Hispanic or Latino **Region:** 33% Rural, 19% Suburban, 5% Urban, 43% Did Not Respond **Teaching Experience:** 19% None, 5% Less than 1 year, 5% 1 to 5 years, 19% 6 to 10 years, 5% 11 to 15 years, 14% 16 to 20 years, 33% More than 20 years	179	0
	June/ August '22[b]	Virtual	4	**State:** 50% Connecticut, 25% Oregon, 25% Wyoming	12	0

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Gender: 100% Female **Ethnicity:** 75% White or Caucasian, 25% Did Not Respond **Region:** 25% Suburban, 75% Did Not Respond **Teaching Experience:** 25% 11 to 15 years, 25% 16 to 20 years, 25% More than 20 years, 25% Did Not Respond		
Montana	January ‘20	Helena, MT	15	Not Collected	149	[a]
	July ‘21[b]	Virtual	3	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	41	0
	June/ August ‘22[b]	Virtual	4	**State:** 50% Connecticut, 25% Oregon, 25% Wyoming **Gender:** 100% Female **Ethnicity:** 75% White or Caucasian, 25% Did Not Respond **Region:** 25% Suburban, 75% Did Not Respond **Teaching Experience:** 25% 11 to 15 years, 25% 16 to 20 years, 25% More than 20 years, 25% Did Not Respond	13	0
Multi-State Science Assessment (Rhode Island and Vermont)	January ‘18	Providence, RI	21	**State:** 100% Rhode Island **Teaching Experience:** 67% General Education, 14% Bilingual Education, 5% Special Education, 5% Science Coordinator, 10% Other	73	14
	March ‘18	Providence, RI	11	**State:** 55% Rhode Island, 45% Vermont	100	24
	January ‘19	Concord, NH	14	**Gender:** 63% Female, 23% Male **Teaching Experience:** 69% General Education, 3% Special Education, 11% Coach, 17% Other	116	18
	November ‘19	Fairlee, VT	17	**State:** 29% Rhode Island, 6% Vermont, 65% Did Not Respond **Gender:** 23% Female, 12% Male, 65% Did Not Respond **Ethnicity**: 35% White or Caucasian, 65% Did Not Respond **Region:** 6% Rural, 17% Suburban, 77% Did Not Respond **Teaching Experience:** 6% 11 to 15 years, 17% 16 to 20 years, 12% More than 20 years, 65% Did Not Respond	66	0
	July ‘20[b]	Virtual	2	**State:** 50% Utah, 50% Vermont **Gender:** 100% Female **Ethnicity**: 50% Hispanic or Latino, 50% White or Caucasian	27	0

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Region: 50% Rural, 50% Did Not Respond **Teaching Experience:** 50% 6 to 10 years, 50% More than 20 years		
	July ‘21[b]	Virtual	3	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	30	1
	August ‘21	Virtual	3	**State:** 100% Rhode Island **Gender:** 100% Female **Ethnicity:** 100% White or Caucasian **Region:** 33% Suburban, 67% Urban **Teaching Experience:** 33% 6 to 10 years, 67% More than 20 years	93	3
Oregon	September ‘17	Salem, OR	5	**Gender:** 100% Female **Region:** 80% Urban, 20% Suburban **Teaching Experience:** 40% General Education, 20% Bilingual Education, 20% Special Education, 60% Administration, 20% Other	235	114
	August ‘18	Salem, OR	39	**Gender:** 74% Female, 26% Male **Ethnicity:** 3% Asian, 8% Hispanic or Latino, 3% Native American, 82% White or Caucasian, 10% Other **Region:** 56% Urban, 44% Rural **Teaching Experience:** 15% General Education, 72% Bilingual Education, 33% Special Education, 33% Other	257	8
	October ‘18	Salem, OR	8	**Gender:** 100% Female **Ethnicity:** 80% White or Caucasian, 20% Other **Region:** 80% Urban, 20% Rural **Teaching Experience:** 88% Bilingual Education, 50% Special Education, 63% Other	60	12
	December ‘18	Virtual	11	**Gender:** 91% Female, 9% Male **Ethnicity:** 9% Hispanic or Latino, 91% White or Caucasian **Region:** 55% Urban, 45% Rural **Teaching Experience:** 27% General Education, 64% Bilingual Education, 18% Special Education, 9% Administration, 64% Other	62	14

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
	October ‘19	Salem, OR	9	**Gender:** 78% Female, 22% Male **Ethnicity:** 89% White or Caucasian, 11% Native American **Region:** 44% Urban, 56% Rural **Teaching Experience:** 89% General Education, 67% Bilingual Education, 44% Special Education	246	23
	January ‘20	Salem, OR	11	**Gender:** 55% Female, 45% Male **Ethnicity:** 100% White or Caucasian **Region:** 45% Urban, 45% Suburban, 9% Rural **Teaching Experience:** 100% General Education, 90% Bilingual Education, 81% Special Education, 81% Other	262	33
	July ‘20[b]	Virtual	2	**State:** 50% Connecticut, 50% Utah **Gender:** 100% Female **Ethnicity**: 50% Hispanic or Latino, 50% Did Not Respond **Region:** 100% Did Not Respond **Teaching Experience:** 50% 6 to 10 years, 50% Did Not Respond	22	3
	August ‘20	Virtual	7	**Gender:** 72% Female, 14% Male, 14% Nonbinary **Ethnicity:** 14% Asian, 43% African American, 29% Hispanic or Latino, 14% Native American **Region:** 14% Urban, 72% Suburban, 14% Rural **Teaching Experience:** 57% General Education, 57% Bilingual Education, 29% Special Education, 29% Administration	86	7
	August ‘21	Virtual	7	**Gender:** 100% Female **Ethnicity:** 100% White or Caucasian **Region:** 14% Urban, 29% Suburban, 57% Rural **Teaching Experience:** 43% General Education, 14% Bilingual Education, 14% Administration, 29% Other	353	13
	July ‘22	Virtual	9	**Gender:** 56% Female, 33% Male, 11% Nonbinary **Ethnicity:** 11% Hispanic or Latino, 89% White or Caucasian **Region:** 22% Rural, 45% Suburban, 33% Urban **Teaching Experience:** 23% 1 to 5 years, 33% 6 to 10 years, 11% 11 to 15 years, 33% More than 20 years	43	2
Rhode Island	October ‘22	Virtual	20	**Gender:** 85% Female, 15% Male **Ethnicity:** 10% Black or African American, 5% Multiracial or Biracial, 85% White or Caucasian **Region:** 10% Rural, 25% Suburban, 30% Urban, 35% Did Not Respond	115	22

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Teaching Experience: 20% 1 to 5 years, 15% 6 to 10 years, 10% 11 to 15 years, 25% 16 to 20 years, 30% More than 20 years		
South Dakota	October ‘19	Pierre, SD	26	**Gender:** 81% Female, 19% Male **Ethnicity:** 4% American Indian or Alaska Native, 4% Asian, 92% White or Caucasian **Region:** 65% Rural, 15% Suburban, 15% Urban, 4% Not Applicable **Teaching Experience:** 12% 1 to 5 years, 12% 6 to 10 years, 19% 11 to 15 years, 19% 16 to 20 years, 38% More than 20 years	[a]	[a]
U.S. Virgin Islands	October ‘21	Virtual	18	**Gender:** 72% Female, 28% Male **Ethnicity**: 6% Asian, 88% Black or African American, 6% White or Caucasian **Region:** 17% Rural, 17% Urban, 11% Suburban, 17% Not Applicable, 38% Did Not Respond **Teaching Experience:** 22% 1 to 5 years, 5% 6 to 10 years, 17% 11 to 15 years, 17% 16 to 20 years, 39% More than 20 years	299	28
Utah	July ‘17	Park City, UT	6	**Gender:** 100% Female **Ethnicity:** 33% American Indian or Alaska Native, 33% Hispanic or Latino, 33% White or Caucasian **Region:** 17% Rural, 83% Did Not Respond **Teaching Experience:** 17% General Education, 17% Special Education, 33% Administration, 33% Other	44	2
	December ‘17	Salt Lake City, UT	6	**Gender:** 83% Female, 17% Make **Ethnicity:** 33% Black or African American, 17% Hispanic or Latino, 33% Native American, 17% Not Applicable **Teaching Experience:** 33% Administration, 83% Other	48	1
	October ‘19	Provo, UT	11	**Gender:** 27% Female, 73% Did Not Respond **Ethnicity**: 9% Hispanic or Latino, 18% White or Caucasian, 73% Did Not Respond **Region:** 9% Urban, 91% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% More than 20 years, 73% Did Not Respond	31	0
	July ‘20[b]	Virtual	9	**Gender:** 22% Female, 78% Did Not Respond **Ethnicity**: 22% Hispanic or Latino, 78% Did Not Respond **Region:** 100% Did Not Respond	38	1

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Teaching Experience: 11% None, 11% 6 to 10 years, 78% Did Not Respond		
	December ‘20	Virtual	6	**Gender:** 50% Female, 50% Did Not Respond **Ethnicity**: 17% Hispanic or Latino, 33% White or Caucasian, 50% Did Not Respond **Region:** 17% Suburban, 83% Did Not Respond **Teaching Experience:** 17% 1 to 5 years, 33% 16 to 20 years, 50% Did Not Respond	14	0
	July ‘21[b]	Virtual	11	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	64	0
	August ‘21	Virtual	6	**Gender:** 100% Female **Ethnicity:** 17% Hispanic or Latino, Native American or Alaskan American, White or Caucasian, Multiracial or Biracial, 83% White or Caucasian **Region:** 33% Rural, 33% Suburban, 17% Urban, 17% Did Not Respond **Teaching Experience:** 17% Less than 1 year, 33% 1 to 5 years, 50% More than 20 years	67	1
	September ‘22	Salt Lake City, UT	28	**Gender:** 81% Female, 19% Male **Ethnicity:** 2% American Indian or Alaska Native, 1% Asian, 2% Hispanic or Latino, 1% Mediterranean, 80% White or Caucasian **Region:** 26% Rural, 52% Suburban, 16% Urban, 7% Not Applicable **Teaching Experience:** 29% 1 to 5 years, 39% 6 to 10 years, 3% 11 to 15 years, 7% 16 to 20 years, 7% More than 20 years, 16% Not Applicable	111	12
West Virginia	January ‘17	Charleston, WV	28[c]	Not Collected	34	[a]
	January ‘19	Charleston, WV	10	**Gender:** 89% Female, 11% Male **Ethnicity:** 11% Black or African American, 89% White or Caucasian **Region:** 100% Rural	191	[a]

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Teaching Experience: 100% General Education		
	July '21[b]	Virtual	2	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond **Teaching Experience:** 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years	12	1
	June/ August '22[b]	Virtual	3	**State:** 33% Hawaii, 67% Utah **Gender:** 100% Female **Ethnicity:** 33% Asian or Pacific Islander, 33% White or Caucasian, 33% Multiracial or Biracial **Region:** 33% Suburban, 67% Did Not Respond **Teaching Experience:** 33% None, 33% 11 to 15 years, 33% More than 20 years	13	0
Wyoming	December '17	Cheyenne, WY	5	Not Collected	32	3
	October '18	Cheyenne, WY	5	Not Collected	39	0
	November '19	Cheyenne, WY	7	**Gender:** 14% Female, 86% Male **Teaching Experience:** 14% 6 to 10 years, 57% 11 to 20 years, 29% 21 or more years	44	1
	August '20	Virtual	14	**Gender:** 29% Female, 7% Male, 64% Did Not Respond **Ethnicity**: 36% White or Caucasian, 64% Did Not Respond **Region:** 22% Rural, 78% Did Not Respond **Teaching Experience:** 7% 11 to 15 years, 7% 16 to 20 years, 22% More than 20 years, 64% Did Not Respond	37	1
	June/ July '21	Virtual	6	**Gender:** 67% Female, 17% Male, 17% Did Not Respond **Ethnicity:** 83% White or Caucasian, 17% Did Not Respond **Region:** 50% Rural, 17% Suburban, 33% Did Not Respond **Teaching Experience:** 17% 6 to 10 years, 50% 11 to 15 years, 17% More than 20 years, 17% Did Not Respond	39	39
	July '21[b]	Virtual	4	**State:** 22% Connecticut, 4% Hawaii, 9% Idaho, 4% Montana, 4% Oregon, 4% Rhode Island, 13% South Dakota, 4% Utah, 3% Vermont, 12% West Virginia, 13% Wyoming, 4% Did Not Respond	28	0

State/Item Bank	Date	Location	Number of Committee Members	Fairness Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Teaching Experience: 9% 1 to 5 years, 18% 6 to 10 years, 29% 11 to 15 years, 19% 16 to 20 years, 25% More than 20 years		
	June/ August '22[b]	Virtual	6	**State:** 17% Connecticut, 17% Hawaii, 50% Utah, 17% West Virginia **Gender:** 100% Female **Ethnicity:** 17% Asian or Pacific Islander, 50% White or Caucasian, 33% Multiracial or Biracial **Region:** 17% Suburban, 17% Urban, 67% Did Not Respond **Teaching Experience:** 33% None, 33% 11 to 15 years, 33% More than 20 years	37	0

[a]As of the time of writing this report, the number of science items reviewed and/or rejected by Fairness Committees is not currently available.
[b]Items were reviewed in a combined Fairness Committee Meeting that included ICCR and MOU state-owned items. Items reviewed in the combined meetings are displayed by their respective state or bank of ownership.
[c]The number of Committee Members includes the total members across ELA, math, and science committees. The specific number of science committee members is currently unavailable.

Appendix 2-G

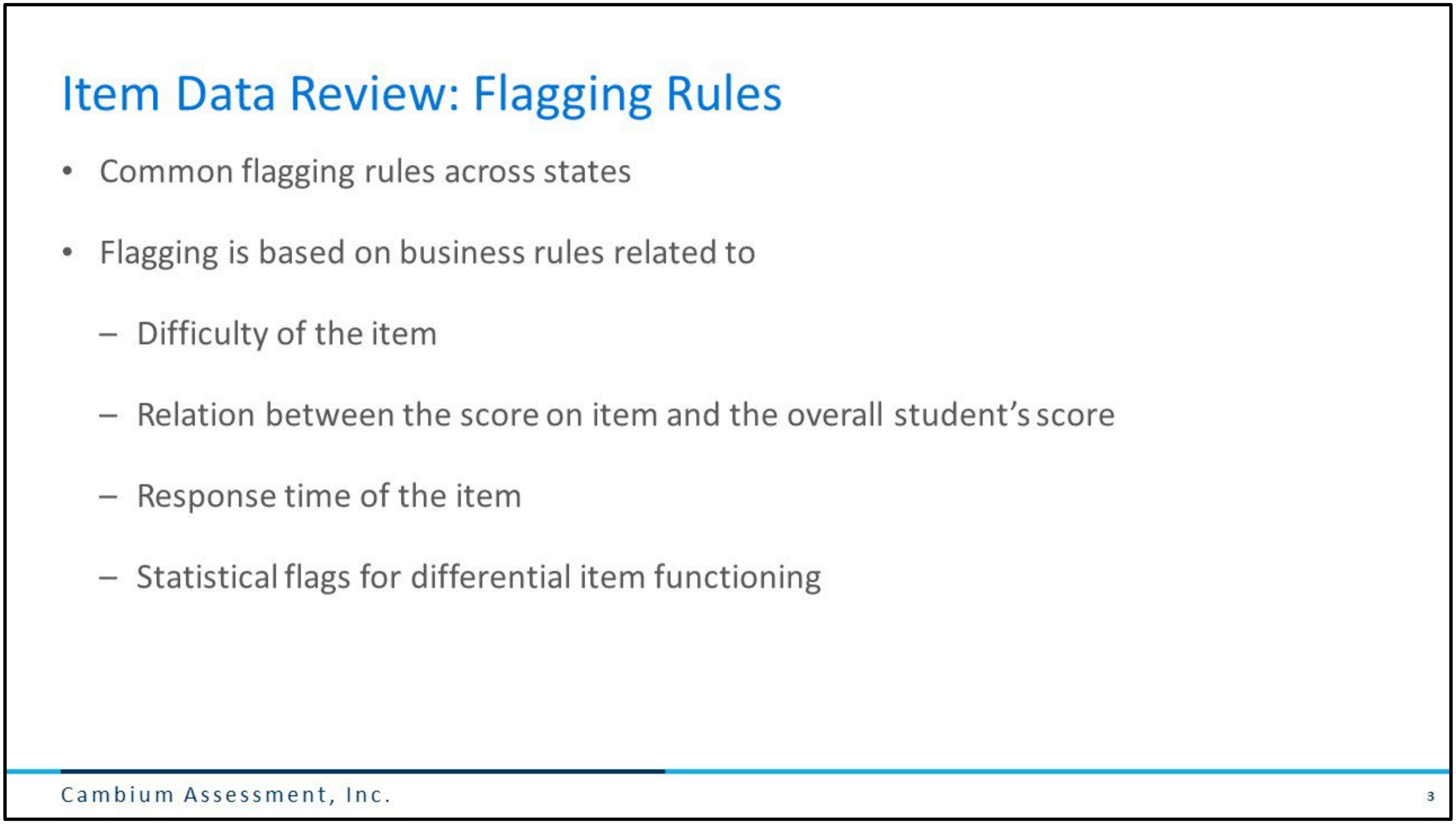
Sample Data Review Training Materials

Sample Data Review Training Materials

Item Data Review

- Item Data Review is the final step before items move to the operational pool
- For every state: data review is carried out for the items owned by the state
- Decision to send an item to data review is based on empirical data
- Statistics are computed at the assertion-level
- Inclusion in data review is decided at the item level, not at the assertion level
  - Inclusion in data review is based on statistical flags that rely on assertion level statistics but are evaluated for the entire item

Cambium Assessment, Inc. 2


Item Data Review: Flagging Rules
• Common flagging rules across states
• Flagging is based on business rules related to
– Difficulty of the item
– Relation between the score on item and the overall student's score
– Response time of the item
– Statistical flags for differential item functioning
Cambium Assessment, Inc.
3

Flagging Rules: *P*-value

- The *p*-value is the proportion of students for which the assertion is TRUE
- Corresponds to the difficulty of an item in a traditional assessment
- Across an item bank, we want to see assertions with *p*-values across the full range to be able to precisely measure proficiency across all proficiency levels
  - A low *p*-value is not bad per se
- However, we want to make sure the low *p*-value is not a result of an item being misleading

Cambium Assessment, Inc. 4

Flagging Rules: *P*-value

- Criteria for clusters:
  - average *p*-value < .30 (across the assertions within a cluster)
  - average *p*-value > .85 (across the assertions within a cluster)
- Criteria for stand-alone items (typically has 1-3 assertions):
  - average *p*-value < . 15 (across the assertions within a stand-alone item)
  - average *p*-value > .95 (across the assertions within a stand-alone item)

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5

Flagging Rules: Item-Total Correlation

- We expect students who do well on the test overall to have a higher probability of doing well on individual assertions
- The item-total correlation describes that relation
- Criteria
  - Average item-total (biserial) correlation < .25
  - One or more assertions with an item-total correlation < 0.05

Cambium Assessment, Inc. 6

Flagging Rules: Differential Item Functioning

- Fair items behave similar across groups
- Probability of answering correctly is the same for all students of similar ability regardless of group membership
- Groups are defined by
  - Gender
  - Ethnicity
  - Economically disadvantaged vs. not
  - ELL vs. not ELL
  - Special Education vs. not

Cambium Assessment, Inc. 7

Flagging Rules: Differential Item Functioning

- Method: Mantel-Haenszel (Holland & Thayer, 1988)
  - Compares performance on an item (i.e., assertion for assertion-based scoring) between reference and focal groups conditional on overall performance
  - Using the theta estimate as stratification variable

Cambium Assessment, Inc. 8

Flagging Rules: Differential Item Functioning

- Severity of possible bias based on significance testing and effect size
  - "A" No statistical evidence of DIF
  - "B" Evidence for potential mild DIF
  - "C" Evidence for potential severe DIF
- Direction of possible bias
  - "–" assertion favors reference groups (e.g., whites/male/non ELLs)
  - "+" assertion favors focal group

Cambium Assessment, Inc. 9

Flagging Rules: Differential Item Functioning

- DIF Criterion
  - For clusters: 2 or more assertions show ‘C’ DIF in the same direction
  - For stand-alone items: 1 or more assertions show ‘C’ DIF in the same direction

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10

Flagging Rules: Timing

- We want a good balance between the amount of information an item provides, and the time students spend on the item
- Criteria
  - For clusters: percentile 80 > 15 minutes
    - » A percentile 80 of *x* minutes: 80% of the students spent *x* minutes or less on the item
  - For stand-alone items: percentile 80 > 3 minutes
  - Assertions per minute < .5 for clusters and stand-alone items

Cambium Assessment, Inc. 11

Item Data Review: Process

- Facilitator presents the item
- Item is presented with information on
  - Grade
  - Discipline
  - Disciplinary Core Idea
  - Performance Expectation
- Statistics on the assertions of the item are presented
  - Including the reason for flagging

Cambium Assessment, Inc. 12

Item Data Review: Process

- Evaluation of item (stimulus, interactions, assertions)
- For every item, one of the following decisions is made
  - Reject
  - Accept as is

Cambium Assessment, Inc. 13

Appendix 2-H

Data Review Committee Participant Details

Data Review Committee Participant Details

Table H-1. Data Review Committee Participants, Science

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
Connecticut	August ‘18	New Britain, CT	29	**Gender:** 88% Female, 12% Male	18	11
	August ‘19	Cromwell, CT	29	**Gender:** 83% Female, 17% Male	53	17
	August ‘21	Virtual	19	**Gender:** 63% Female, 21% Male, 16% Did Not Respond **Ethnicity:** 84% White or Caucasian, 16% Did Not Respond **Region:** 21% Suburban, 21% Urban, 58% Did Not Respond **Teaching Experience:** 5% 1 to 5 years, 5% 6 to 10 years, 16% 11 to 15 years, 21% 16 to 20 years, 37% More than 20 years, 16% Did Not Respond	51	12
	August ‘22	Virtual	15	**Gender:** 73% Female, 20% Male, 7% Did Not Respond **Ethnicity:** 7% Hispanic or Latino, 87% White or Caucasian, 7% Did Not Respond **Region:** 60% Suburban, 7% Urban, 33% Did Not Respond **Teaching Experience:** 13% 6 to 10 years, 27% 16 to 20 years, 53% More than 20 years, 7% Did Not Respond	19	6
	September ‘23	Virtual	12	**Gender:** 83% Female, 17% Male **Ethnicity:** 100% White or Caucasian **Region:** 8% Rural, 67% Suburban, 17% Urban, 8% Not Applicable **Teaching Experience:** 17% 11 to 15 years, 25% 16 to 20 years, 58% More than 20 years	14	21
Hawaii	August ‘18	Honolulu, HI	18	**Gender:** 72% Female, 28% Male	32	3
	August ‘19	Honolulu, HI	18	**Gender:** 71% Female, 29% Male **Ethnicity:** 12% American Indian and White, 41% Asian, 6% Asian and White, 12% Hispanic and White, 18% Native Hawaiian or Pacific Islander, 12% White or Caucasian **Teaching Experience:** 53% General Education, 6% General Education with SPED Certification, 12% Special Education, 29% Other	37	13

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
	August ‘21[a]	Virtual	7	**State:** 14% Connecticut, 29% Hawaii, 14% Idaho, 29% West Virginia, 14% Wyoming **Gender:** 86% Female, 14% Male **Ethnicity**: 86% White or Caucasian, 14% Did Not Respond **Region:** 14% Rural, 29% Suburban, 57% Did Not Respond **Teaching Experience:** 29% 11 to 15 years, 14% 16 to 20 years, 29% More than 20 years, 14% Did Not Respond	26	8
	August ‘22[a]	Virtual	12	**State:** 17% Connecticut, 17% Hawaii, 8% Idaho, 25% Oregon, 33% Wyoming **Gender:** 75% Female, 25% Male **Ethnicity:** 8% Asian or Pacific Islander, 82% White or Caucasian **Region:** 50% Rural, 42% Suburban, 8% Did Not Respond **Island:** 8% Not Applicable, 8% Oahu, 75% Did Not Respond **Teaching Experience:** 33% 6 to 10 years, 8% 16 to 20 years, 58% More than 20 years	49	8
	August ‘23[a]	Virtual	15	**State:** 7% Connecticut, 13% Hawaii, 20% Montana, 7% New Hampshire, 40% Oregon, 7% Utah, 7% Wyoming **Gender:** 60% Female, 40% Male **Ethnicity:** 13% Asian or Pacific Islander, 7% Hispanic or Latino, 7% Native American or Alaskan, 73% White or Caucasian **Region:** 27% Rural, 13% Urban, 60% Did Not Respond **Teaching Experience:** 20% 1 to 5 years, 27% 6 to 10 years, 7% 11 to 15 years, 47% 16 to 20 years	26	5
ICCR	July ‘18	Virtual	18	Not Collected	84	8
	August ‘19[b]	Virtual	–	–	43	3
	August ‘21[a]	Virtual	11	**State:** 27% Connecticut, 9% Hawaii, 18% Idaho, 36% West Virginia, 9% Wyoming **Gender:** 82% Female, 18% Male **Ethnicity:** 54% White or Caucasian, 46% Did Not Respond **Region:** 9% Rural, 27% Suburban, 64% Did Not Respond **Teaching Experience:** 9% 6 to 10 years, 9% 11 to 15 years, 36% More than 20 years, 46% Did Not Respond	75	6
	August ‘22[a]	Virtual	20	**State:** 15% Connecticut, 20% Idaho, 5% North Dakota, 35% Oregon, 5% South Dakota, 20% Wyoming **Gender:** 85% Female, 15% Male	68	14

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Ethnicity: 5% Asian or Pacific Islander, 95% White or Caucasian **Region:** 30% Rural, 25% Suburban, 15% Urban, 30% Did Not Respond **Teaching Experience:** 10% 1 to 5 years, 35% 6 to 10 years, 15% 16 to 20 years, 40% More than 20 years		
	August ‘23[a]	Virtual	19	**State:** 11% Connecticut, 21% Hawaii, 5% Montana, 5% New Hampshire, 21% Oregon, 16% Utah, 5% West Virginia, 16% Wyoming **Gender:** 74% Female, 26% Male **Ethnicity:** 16% Asian or Pacific Islander, 84% White or Caucasian **Region:** 21% Rural, 11% Suburban, 5% Urban, 63% Did Not Respond **Teaching Experience:** 21% 1 to 5 years, 16% 6 to 10 years, 16% 16 to 20 years, 47% More than 20 years	54	9
Idaho	August ‘19	[c]	10	**Gender:** 70% Female, 20% Male, 1% Did Not Respond **Ethnicity:** 100% White or Caucasian **Region:** 60% Rural, 40% Suburban **Teaching Experience:** 60% General Education, 2% Administration, 2% Coach	12	6
	August ‘21[a]	Virtual	9	**State:** 11% Hawaii, 56% Idaho, 11% West Virginia, 22% Wyoming **Gender:** 89% Female, 11% Male **Ethnicity:** 89% White or Caucasian, 11% Did Not Respond **Region:** 11% Rural, 22% Suburban, 67% Did Not Respond **Teaching Experience:** 22% 6 to 10 years, 22% 11 to 15 years, 11% 16 to 20 years, 33% More than 20 years, 11% Did Not Respond	60	5
	August ‘22[a]	Virtual	8	**State:** 25% Connecticut, 13% Idaho, 25% Oregon, 38% Wyoming **Gender:** 63% Female, 38% Male **Ethnicity:** 13% Hispanic or Latino, 88% White or Caucasian **Region:** 38% Rural, 50% Suburban, 13% Did Not Respond **Teaching Experience:** 13% 1 to 5 years, 13% 6 to 10 years, 25% 11 to 15 years, 13% 16 to 20 years, 38% More than 20 years	4	0

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
	August '23[a]	Virtual	17	**State:** 12% Connecticut, 12% Hawaii, 6% Idaho, 6% Montana, 6% New Hampshire, 24% Oregon, 35% Utah **Gender:** 71% Female, 24% Male, 6% Prefer Not to Say **Ethnicity:** 6% Asian or Pacific Islander, 6% Hispanic or Latino, 6% Native American or Alaskan, 71% White or Caucasian, 12% Did Not Respond **Region:** 29% Rural, 18% Suburban, 53% Did Not Respond **Teaching Experience:** 12% 6 to 10 years, 24% 16 to 20 years, 53% More than 20 years, 12% Did Not Respond	5	0
Montana	September '21	Virtual	4	**Gender:** 50% Female, 50% Did Not Respond **Ethnicity:** 50% White or Caucasian, 50% Did Not Respond **Region:** 50% Rural, 50% Did Not Respond **Teaching Experience:** 25% 6 to 10 years, 25% 16 to 20 years, 50% Did Not Respond	17	4
	September '22	Virtual	5	**Gender:** 100% Female **Ethnicity:** 100% White or Caucasian **Region:** 60% Rural, 40% Suburban **Teaching Experience:** 40% 6 to 10 years, 20% 16 to 20 years, 40% More than 20 years	17	3
	August '23[a]	Virtual	11	**State:** 18% Hawaii, 18% Montana, 9% New Hampshire, 9% Oregon, 36% Utah, 9% West Virginia **Gender:** 100% Female **Ethnicity:** 18% Hispanic or Latino, 73% White or Caucasian, 9% Did Not Respond **Region:** 36% Rural, 64% Did Not Respond **Teaching Experience:** 9% 6 to 10 years, 18% 16 to 20 years, 64% More than 20 years, 9% Did Not Respond	12	3
Multi-State Science Assessment (Rhode Island and Vermont)	August '18	Virtual	–	–	9	6
	August '19	Virtual	–	–	14	4
	August '21	Virtual	–	–	18	9
	September '22	Virtual	–	–	11	7
Oregon	September '18	Salem, OR	11	**Gender:** 82% Female, 18% Male **Ethnicity:** 100% White or Caucasian **Region:** 73% Rural, 27% Urban	44	6

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Teaching Experience: 64% General Education, 55% Bilingual Education, 36% Special Education, 18% Administration, 18% Other		
	August ‘19	Virtual	4	**Gender:** 50% Female, 50% Male **Ethnicity:** 100% White or Caucasian **Region:** 50% Rural, 50% Urban **Teaching Experience:** 50% General Education, 25% Bilingual Education, 25% Special Education, 25% Administration, 75% Other	8	7
	August ‘22[a]	Virtual	8	**State:** 38% Connecticut, 38% Idaho, 13% Wyoming, 13% Did Not Respond **Gender:** 75% Female, 13% Male, 13% Did Not Respond **Ethnicity:** 88% White or Caucasian, 13% Did Not Respond **Region:** 25% Rural, 13% Suburban, 25% Urban, 38% Did Not Respond **Teaching Experience:** 25% 6 to 10 years, 13% 11 to 15 years, 13% 16 to 20 years, 38% More than 20 years, 13% Did Not Respond	31	8
	August ‘23[a]	Virtual	16	**State:** 6% Connecticut, 6% Idaho, 13% Montana, 38% Oregon, 19% Utah, 6% West Virginia, 13% Wyoming **Gender:** 75% Female, 19% Male, 6% Prefer Not to Say **Ethnicity:** 13% Asian or Pacific Islander, 6% Native American or Alaskan, 75% White or Caucasian, 6% Did Not Respond **Region:** 13% Rural, 19% Suburban, 6% Urban, 63% Did Not Respond **Teaching Experience:** 19% 1 to 5 years, 25% 6 to 10 years, 25% 16 to 20 years, 25% More than 20 years, 6% Did Not Respond	12	2
Rhode Island	September ‘23	Virtual	–	–	17	6
South Dakota	September ‘21	Virtual	–	–	15	0
	September ‘22	Virtual	–	–	4	1
	September ‘23	Virtual	–	–	6	2
Utah	August ‘18	Salt Lake City, UT	16	**Gender:** 93% Female, 7% Male **Ethnicity:** 87% White or Caucasian, 13% Did Not Respond **Region:** 13% Suburban, 27% Rural, 60% Did Not Respond **Teaching Experience:** 100% General Education	40	6
	September ‘21	Virtual	6	**Gender:** 63% Female, 38% Male	11	3

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Ethnicity: 13% Native Hawaiian or Pacific Islander, 88% White or Caucasian **Region:** 50% Rural, 13% Suburban, 38% Urban **Teaching Experience:** 38% 6 to 10 years, 38% 11 to 15 years, 25% More than 20 years		
	September ‘22	Salt Lake City, UT	17	**Gender:** 88% Female**,** 13% Male **Ethnicity:** 6% Asian, 12% Hispanic or Latino, 6% Mixed, 77% White or Caucasian **Region:** 12% Rural, 41% Suburban, 41% Urban, 6% Not Applicable **Teaching Experience:** 6% Less than 1 year, 29% 1 to 5 years, 36% 6 to 10 years, 18% 11 to 15 years, 12% More than 20 years	11	6
	September ‘23	Salt Lake City, UT	20	**Gender:** 70% Female, 30% Male **Ethnicity:** 5% Asian, 10% Hispanic, 10% Latino, 75% White or Caucasian **Region:** 10% Rural, 50% Suburban, 25% Urban, 15% Not Applicable **Teaching Experience:** 10% Less than 1 year, 25% 1 to 5 years, 20% 6 to 10 years, 20% 11 to 15 years, 10% More than 20 years, 10% Not Applicable, 5% Did Not Respond	6	0
West Virginia	July ‘18	[c]	4	Not Collected	3	1
	September ‘19	[c]	4	Not Collected	7	6
	August ‘21[a]	Virtual	4	**State:** 25% Hawaii, 50% West Virginia, 25% Wyoming **Gender:** 100% Female **Ethnicity**: 75% White or Caucasian, 25% Did Not Respond **Region:** 25% Rural, 25% Suburban, 50% Did Not Respond **Teaching Experience:** 50% 11 to 15 years, 25% More than 20 years, 25% Did Not Respond	7	3
	August ‘22[a]	Virtual	9	**State:** 22% Connecticut, 33% Idaho, 11% Oregon, 33% Wyoming **Gender:** 89% Female, 11% Male **Ethnicity:** 100% White or Caucasian **Region:** 56% Rural, 11% Suburban, 11% Urban, 22% Did Not Respond **Teaching Experience:** 11% 1 to 5 years, 22% 6 to 10 years, 11% 11 to 15 years, 11% 16 to 20 years, 44% More than 20 years	10	4

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
	August '23[a]	Virtual	11	**State:** 9% Connecticut, 18% Hawaii, 9% Montana, 9% New Hampshire, 9% Oregon, 45% Utah **Gender:** 82% Female, 9% Male, 9% Prefer Not to Say **Ethnicity:** 9% Hispanic or Latino, 82% White or Caucasian, 9% Did Not Respond **Region:** 36% Rural, 9% Suburban, 56% Did Not Respond **Teaching Experience:** 9% 6 to 10 years, 27% 16 to 20 years, 56% More than 20 years, 9% Did Not Respond	12	3
Wyoming	October '18	Cheyenne, WY	12	**Gender:** 75% Female, 25% Male **Teaching Experience:** 8% 3 to 5 years, 8% 6 to 10 years, 58% 11 to 20 years, 25% 21 or more years	16	6
	August '19	Cheyenne, WY	10	**Gender:** 90% Female, 10% Male **Region:** 40% Suburban, 60% Rural **Teaching Experience:** 90% General Education, 10% Administration	16	5
	August '21[a]	Virtual	8	**State:** 38% Connecticut, 13% Hawaii, 13% West Virginia, 38% Wyoming **Gender:** 75% Female, 25% Male **Ethnicity**: 75% White or Caucasian, 25% Did Not Respond **Region:** 13% Rural, 25% Suburban, 13% Urban, 50% Did Not Respond **Teaching Experience:** 13% 11 to 15 years, 63% More than 20 years, 25% Did Not Respond	16	4
	August '22[a]	Virtual	12	**State:** 17% Connecticut, 8% Hawaii, 17% Idaho, 17% Oregon, 42% Wyoming **Gender:** 67% Female, 33% Male **Ethnicity:** 8% Asian or Pacific Islander, 8% Hispanic or Latino, 83% White or Caucasian **Region:** 42% Rural, 50% Suburban, 8% Did Not Respond **Teaching Experience:** 8% 1 to 5 years, 25% 6 to 10 years, 17% 11 to 15 years, 8% 16 to 20 years, 42% More than 20 years	19	3
	August '23[a]	Virtual	17	**State:** 12% Connecticut, 12% Hawaii, 6% Idaho, 6% Montana, 6% New Hampshire, 24% Oregon, 35% Utah **Gender:** 71% Female, 24% Male, 6% Prefer Not to Say **Ethnicity:** 6% Asian or Pacific Islander, 6% Hispanic or Latino, 6% Native American or Alaskan, 71% White or Caucasian, 12% Did Not Respond	8	1

State/Item Bank	Date	Location	Number of Committee Members	IDR Committee Member Demographic Summary	Number of Items Reviewed	Number of Items Rejected by Committees
				Region: 29% Rural, 18% Suburban, 53% Did Not Respond **Teaching Experience:** 18% 6 to 10 years, 18% 16 to 20 years, 53% More than 20 years, 12% Did Not Respond		

Note. MSSA, Rhode Island, and South Dakota-owned items were reviewed by Rhode Island Department of Education and Vermont Agency of Education science content experts, the Rhode Island Department of Education, and the South Dakota Department of Education, respectively.
[a]Combined Item Data Review Meetings were conducted for multiple states in 2021, 2022, and 2023 (184 items were reviewed in the combined meeting format for Hawaii, Idaho, West Virginia, Wyoming, and ICCR items in 2021; 181 items were reviewed in the combined meeting format for Hawaii, Idaho, Oregon, West Virginia, Wyoming, and ICCR items in 2022, and 129 items were reviewed in the combined meeting format for Hawaii, Idaho, Montana, Oregon, West Virginia, Wyoming, and ICCR items in 2023). In 2021, 25 committee members took part in the combined Item Data Review Meetings; in 2022, 38 committee members participated in the combined Item Data Review Meetings, and in 2023, 41 committee members participated in the combined Item Data Review Meetings. Items reviewed in the combined meetings are displayed by their respective state or bank of ownership.
[b]During the summer 2019, ICCR field-test items underwent committee review in Connecticut, Hawaii, and Idaho.
[c]The specific location of the Data Review Committee Meeting is unavailable at the time of writing this report.

Appendix 2-I

Example Item Interactions

Interaction Types Available in the ISAT in Science

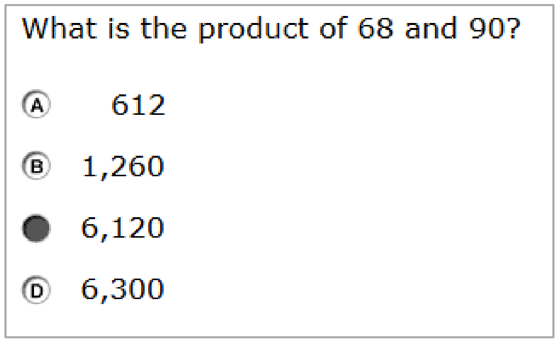
Review of Different Interaction Types

Interaction Type	Associated Sub-Types	Legacy Item Types Supported
Choice	Multiple Choice	MC
	Multiple Select	MS
	Scaffolding	ASI2, ASI3
Text Entry	Simple Text Entry	EA, ECR, LA, OE, SA, SR, WCR, RW, SCR
	Embedded Text Entry	CL, FI
	Natural Language	NL
	Extended Response	ER
Table	Table Match	MI
	Table Input	TI
	Column Match	MI
Edit Task	Edit Task	ET
	Edit Task with Choice	ETC
	Edit Task Inline Choice	ETC
Hot Text	Selectable	HTQ
	Re-orderable	HT
	Drag-from-Palette	DnD
	Custom	HTQ, HT, DnD
Equation	N/A	EQN
Grid	Grid	GI
	Hot Spot	GI
	Graphic Gap Match	GI
Simulation*	N/A	SIM

Note. the abbreviations correlate to the attributes used in AIR's Item Tracking System

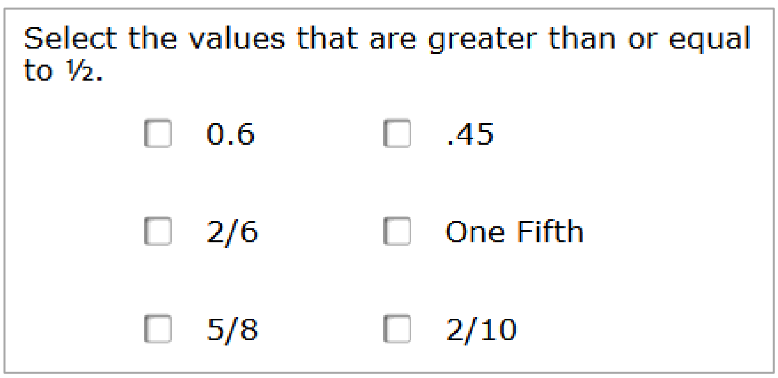
Multiple-Choice Interactions

Multiple-Choice (MC) interactions require students to select a single option from a list of possible answer options. The number and orientation of answer options in a multiple-choice interaction are configurable. Answer options may appear vertically, horizontally, vertically-stacked (in a specified number of columns), or horizontally-stacked (in a specified number of rows).



Multiple-Select Interactions

Multiple-Select interactions require students to select one or more options from a list of possible answer options. The number and orientation of answer options in a multiple-select interaction are configurable. Answer options may appear vertically, horizontally, horizontally-stacked (in a specified number of rows), or vertically-stacked (in a specified number of columns).



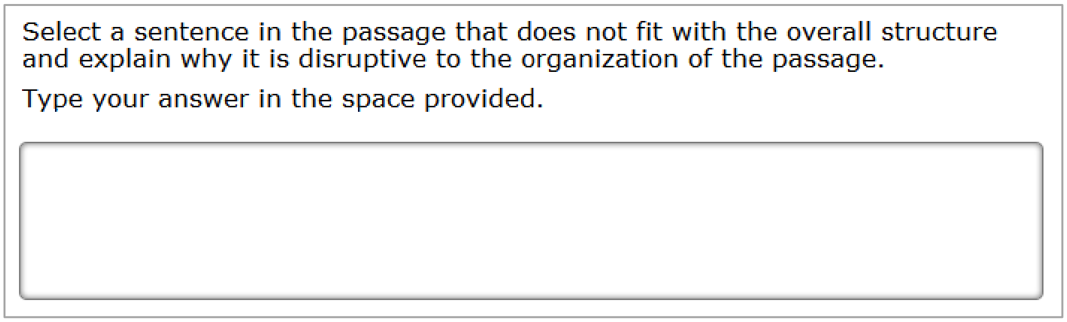
Text Entry Interactions

The Text Entry Interaction Editor allows you to create content for the following interaction types:

- Simple Text Entry Interactions
- Embedded Text Entry Interactions
- Natural Language Interactions
- Extended Response Interactions

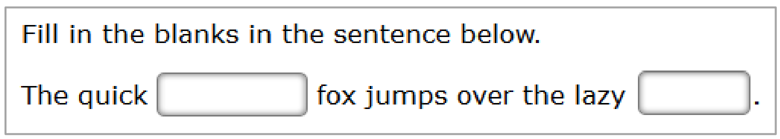
Simple Text Entry Interactions

Simple Text Entry interactions require students to type a response in a text box. For Simple Text Entry interactions, we can allow you to specify the maximum response length for the text box and the type of text editor available to students.



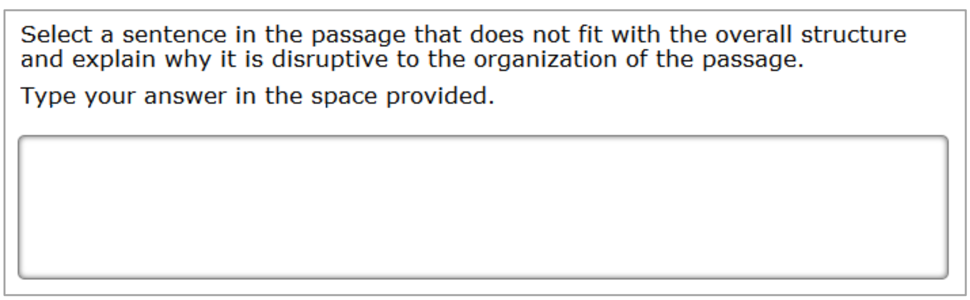
Embedded Text Entry Interactions

Embedded Text Entry interactions require students to type their response in one or more text boxes that are embedded in a section of read-only text.



Extended Response Interactions

Extended Response interactions require students to type a response in a text box. Extended Response interactions are scored by an uploaded essay scoring model that analyzes the student's response to identify variations of acceptable key words and phrases. For Extended Text Entry interactions, we can allow you to specify the maximum response length for the text box and the type of text editor available to students.



Alert: Extended Response interactions cannot be combined with any other interactions in the item.

Table Entry Interaction

The Table Entry Interaction Editor allows you to create content for the following interaction types:

- Table Match Interactions
- Table Input Interactions
- Column Match Interactions

Table Match Interactions

Table Match interactions arrange two sets of match options in a table, with one set listed in columns and the other set listed in rows. Students match options in the columns to options in the rows by marking checkboxes in the cells where the columns and rows intersect.

For each number listed in the rows of the table, mark the checkboxes for each column that describes that number.

	Perfect Square	**Prime Number**	**Odd Number**	**Even Number**
5	☐	☐	☐	☐
12	☐	☐	☐	☐
9	☐	☐	☐	☐

Table Match interactions allow you to customize the number of match options in each set and enter the content for each match option. You can also set restrictions on the number of matches students can make. By default, the panel includes a basic table consisting of three rows and columns (including the row header and column header).

Table Input Interactions

Table Input interactions provide students with a table that includes one or more blank cells. Each blank cell displays a text box in which students can type their response.

Enter a stage direction that you might give to each theater technician listed in the table below.

The first one has been done for you.

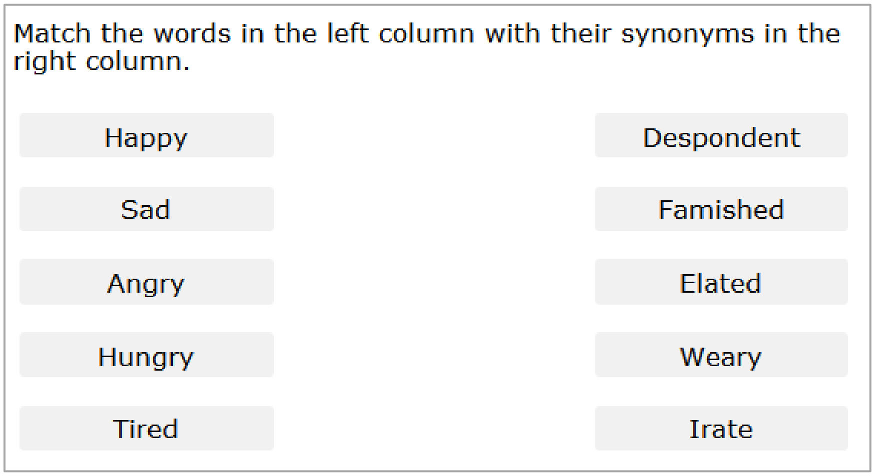
Theater technicians	Stage direction
Set designer	A circular bench around a small obelisk
Props manager	
Sound technician	
Lighting technician	

Table Input interactions allows you to customize the number of rows and columns in the table, specify which cells display text boxes, and enter content for the read-only cells. By default, the panel includes a basic table consisting of three rows and columns (including the row header and column header).

Alert: If a table does not include row headers, then it must include column headers. If a table does not include column headers, then it must include row headers.

Column Match Interactions

Column Match interactions provide students with two columns that each contain a set of match options. Students respond to the interaction by selecting a match option in the left column and then selecting the corresponding match option in the right column. A match option in one set may have one, multiple, or no matches in the other set.



Column Match interactions allows you to customize the number of match options in each set and enter the content for each match option. By default, the panel includes two single-column tables, each of which includes two match options. You can also set restrictions on the number of matches students can make.

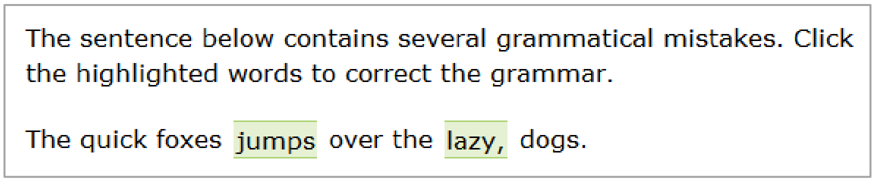
Edit Task Interactions

The Edit Task Interaction Editor allows you to create content for the following interaction types:

- Edit Task Interactions
- Edit Task with Choice Interactions
- Edit Task Inline Choice Interactions

Edit Task Interactions

Edit Task interactions provide students with a sentence or paragraph containing one or more tagged text elements. Tagged elements usually contain an error, such as improper spelling or grammar. To respond to these interactions, students click a tagged element and enter corrected text in an editing window. The entered text replaces the original tagged text.



Edit Task interactions allow you to enter the text that appears in the response area and tag elements within the text that students can edit.

Warning: You cannot include hand-scored and machine-scored interactions in the same item.

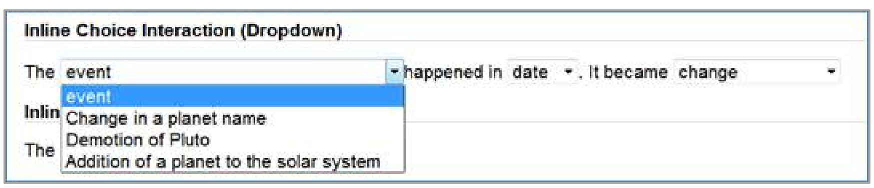
Edit Task with Choice Interactions

Edit Task with Choice interactions are similar to Edit Task interactions. The only difference is that when responding to Edit Task with Choice interactions, students replace the tagged text elements with options selected from a drop-down list.

Edit Task with Choice interactions allow you to enter the text that appears in the response area and tag elements within the text that students can edit.

Edit Task Inline Choice Interactions

Edit Task Inline Choice interactions are similar to Edit Task with Choice interactions. The only difference is that students select replacement options from a drop-down list embedded within the read-only text, rather than accessing the drop-down list via a pop-up window.



Hot Text Interactions

The Hot Text Interaction Editor allows you to create content for the following interaction types:

- Selectable Hot Text Interactions
- Re-orderable Hot Text Interactions
- Drag-from-Palette Hot Text Interactions
- Custom Hot Text Interactions

Selectable Hot Text Interactions

Selectable Hot Text interactions require students to select one or more text elements in the response area.

> Select the sentences that support the inference that the area is in danger of losing its moose population. Select **all** that apply.
>
> A similar boom-and-bust cycle occurs between predator and prey. Ten times the size of a wolf, a moose has long, strong legs and a dangerous kick. So wolves prey mainly on old and weak animals. Good hunting means food for the whole pack. Wolves then raise lots of pups, and their numbers increase. More wolves mean more mouths to feed and more moose get eaten. However, when the moose population decreases, wolves starve.

Selectable Hot Text interactions allows you to set the minimum and maximum number of elements students can select, enter the text that appears in the response area, and tag the text elements that will be selectable.

Re-orderable Hot Text Interactions

Re-orderable Hot Text interactions require students to click and drag hot text elements into a different order.

> Place the following sentences in the correct order.
>
> Hey Jude. And make it better. Don't be afraid. Take a sad song.

Re-orderable Hot Text interactions allow you to enter the re-orderable text elements in the response area. You can specify the elements' orientation and set them to appear in random order to students.

Drag-from-Palette Hot Text Interactions a.k.a. Hot Text Gap Match

Drag-from-Palette Hot Text interactions require students to drag elements from a palette into the available blank table cells or "gaps" (text boxes) in the response area. Palette elements may consist of text and/or images. Students may be able to drag the same palette element into multiple gaps, depending on the interaction's configuration.

Drag and drop the characteristics into the appropriate table cells below.

Fortunato's character	Montressor's character

Sinister and calculating
Cowardly and irreverent
Egotistical and rude
Lazy and inconsiderate

Drag-from-Palette Hot Text interactions allow you to enter the elements that appear in the palette, enter static text for the response area, and create the gap targets where students can drag the text elements. You can enter all of the elements in a single text box or enter each segment in its own text box.

- Can set a minimum/maximum number of times a student is required/allowed to use a specific palette object
- Only supports drag-and-drop of palette items (images or plain text) onto pre-defined drop targets (“gaps” or “blanks”) in the body text
    - These palette items are always confined to a special palette region (no “preplacing” them)
    - There is some control over palette placement
    - The items can only be placed in predefined “target” regions

Custom Hot Text Interactions

Custom Hot Text interactions combine the functionality of the other Hot Text interaction sub-types. Students responding to a Custom Hot Text interaction may need to select text elements, rearrange text elements, and/or drag text elements from a palette to blank table cells or drop targets in the response area. In many ways, this is the grid of the text-interaction world. In practice, it is typically used to do drag-and-drop with text, but it can technically do more:

- Supports dragging and dropping text elements onto drop target areas
    - Text elements can originally be placed anywhere in the interaction (there’s no dedicated palette)
    - Multiple elements can be dropped onto a target
        - this constitutes a “group”
        - much like grid hotspots, you can set constraints on the group

        - Supports selectable text elements

    - Like grid hotspots, these too can be grouped

> Use the word bank to fill in the blank in the sentence below. Then, select all the words in the sentence that are nouns.
>
> **Word bank**:
>
> *young   dull   good   rich*
>
> **Sentence**:
>
> *All work and no play makes Jack a _________ boy.*

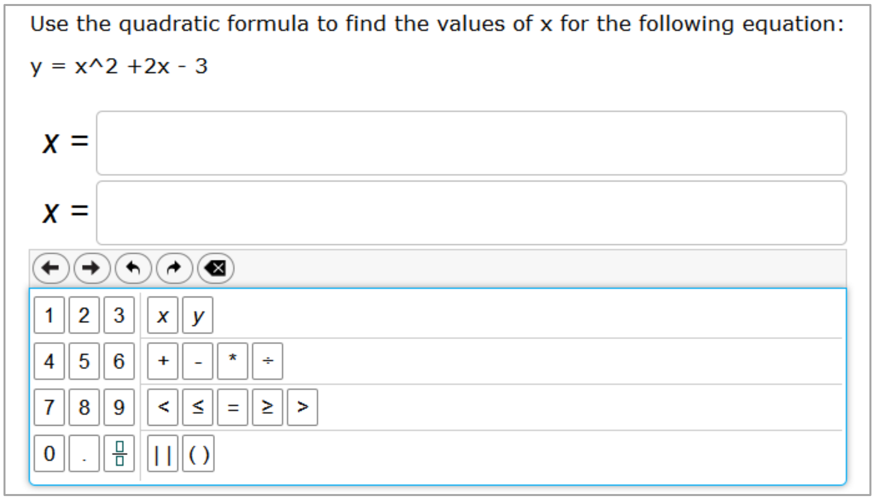
Custom Hot Text interactions allow you to create groups of text elements, as well as the drop targets and static text that appear in the response area. When you create a group of text elements, you must assign a Hot Text functionality to that group. The following functionalities are available:

- **Selectable:** When you assign this functionality to a group, the text elements in the group behave like elements in a Selectable Hot Text interaction. You cannot add drop target elements to this kind of group.
- **Draggable:** When you assign this functionality to a group, the text elements in the group behave like elements in a Re-Orderable Hot Text interaction. If you assign this functionality to a group and also add drop targets to the group, the text elements in the group behave like elements in a Drag-from-Palette Hot Text interaction.

You can create as many groups as you wish, but you can only assign one Hot Text functionality to each group.

Equation Interaction Editor

The Equation Interaction Editor allows you to create content for Equation interactions only. Equation interactions require students to enter a response into input boxes using an on-screen keypad, which may consist of special mathematics characters. Students can also enter their response via a physical keyboard, but they cannot enter any characters that are not included in the on-screen keyboard.



Equation interactions allow you to select the buttons to include in the on-screen keypad, enter static text in the response area, and specify the number of input boxes to include in the response area. When selecting buttons to include in the keypad, you can add individual buttons or an entire row or tab of buttons.

Grid Interactions

The Grid Interaction Editor allows you to create content for the following interaction types:

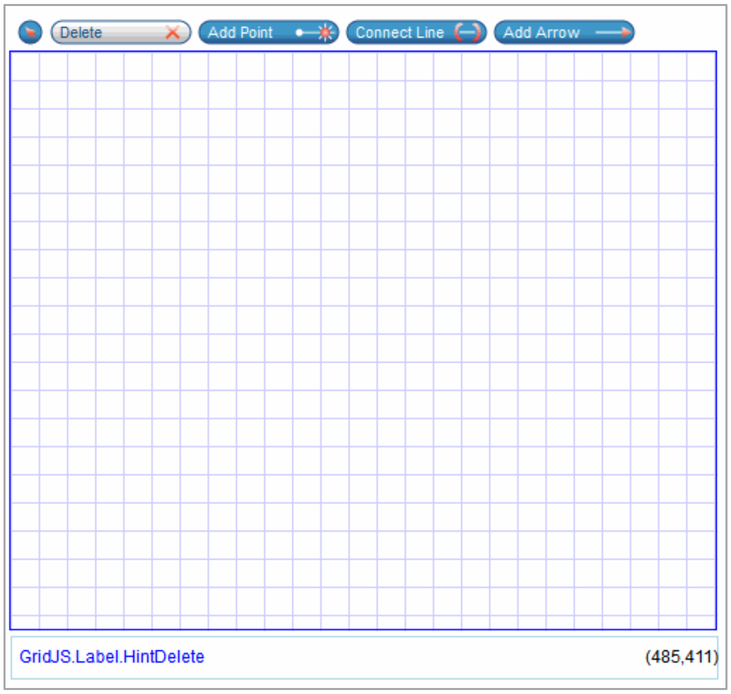
- Grid Interactions
- Hot Spot Interactions
- Graphic Gap Match Interactions

Note: Although there are three options available in the **Interaction Type** drop-down list, the generic **Grid** option allows you to create interactions with functionality similar to Hot Spot and Graphic Gap Match sub-types.

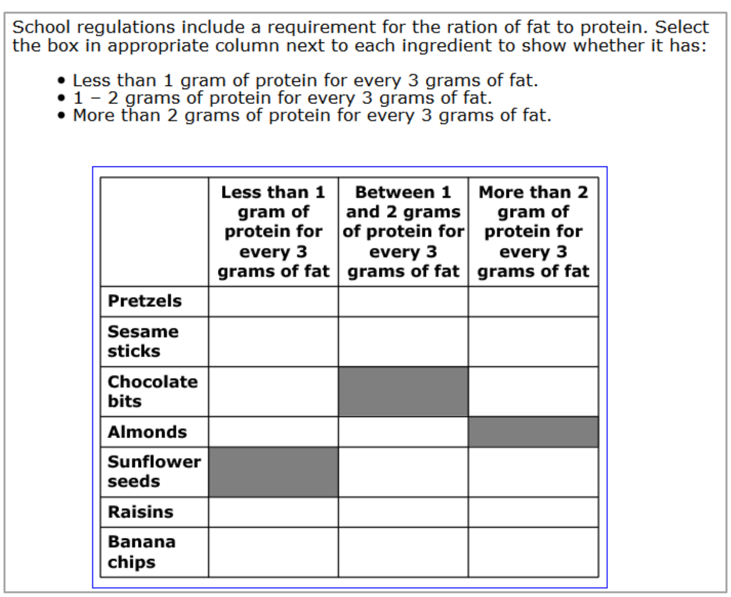
Grid Interactions Types

Grid interactions require students to enter a response by interacting with a grid area in the answer space. There are three general ways in which students can interact with the grid area.

- **Graphing Functionality:** Students can use various tool buttons to add points, lines, and other geometric shapes to the grid area. Only the Grid interaction sub-type allows you to create interactions with this functionality.



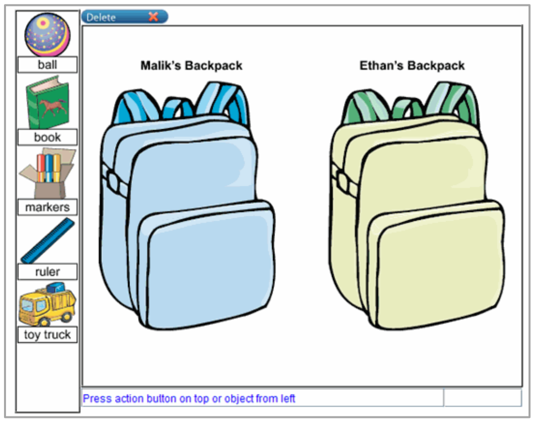
- **Hot Spot Functionality:** Students can click or hover over interactive regions in the grid area (hot spots) in order to activate them. Activated hot spots become highlighted, become outlined, or display an image. The Grid and Hot Spot interaction sub-types allow you to create interactions with this functionality.
  - Hotspots can be defined in groups, each of which can have its own selection constraints
  - These regions support events so clicking a hotspot might change the appearance of the interaction by showing/hiding other images, for example


School regulations include a requirement for the ration of fat to protein. Select the box in appropriate column next to each ingredient to show whether it has:

- Less than 1 gram of protein for every 3 grams of fat.
- 1 – 2 grams of protein for every 3 grams of fat.
- More than 2 grams of protein for every 3 grams of fat.

	Less than 1 gram of protein for every 3 grams of fat	Between 1 and 2 grams of protein for every 3 grams of fat	More than 2 gram of protein for every 3 grams of fat
Pretzels			
Sesame sticks			
Chocolate bits			
Almonds			
Sunflower seeds			
Raisins			
Banana chips			

- **Drag-and-Drop Functionality:** Students can click image or text objects and drag them into various locations in the grid area. The objects for these interactions are either provided in a palette beside the grid area or pre-placed within the grid area itself. The Grid and Graphic Gap Match interaction sub-types allow you to create interactions with this functionality; however, only Graphic Gap Match interactions allow text objects.
    - These palette items can be "preplaced" on the canvas or listed in a separate palette
    - The items can be placed anywhere on the canvas or guided to specific regions with snap points



Note: The functionalities of these interaction types are not mutually exclusive. A single Grid interaction may require students to select hot spots and place objects, or graph lines and select hot spots, and so on. However, a Grid interaction cannot include preplaced objects if it also includes the **Delete** tool button above the grid area.

Grid Hot Spot Interactions

Hot Spot interaction sub-types allow you to create Grid interactions with hot spot functionality. These interactions require students to select hot spot regions in the grid area.

- Only supports click-to-select "hotspots"
    - No visual side-effect events are supported
    - No hotspot groups are supported

Grid Graphic Gap Match Interactions

Graphic Gap Match interactions allow you to create Grid interactions with both hot spot and drag-and-drop functionality. These interactions require students to drag image objects from a palette to hot spot regions (gaps) in the grid area.

- Only supports drag-and-drop of palette items (images or plain text) onto the canvas/background

- These palette items are always confined to a special palette region (no “preplacing” them on the canvas)
- The items can only be placed in predefined “target” regions

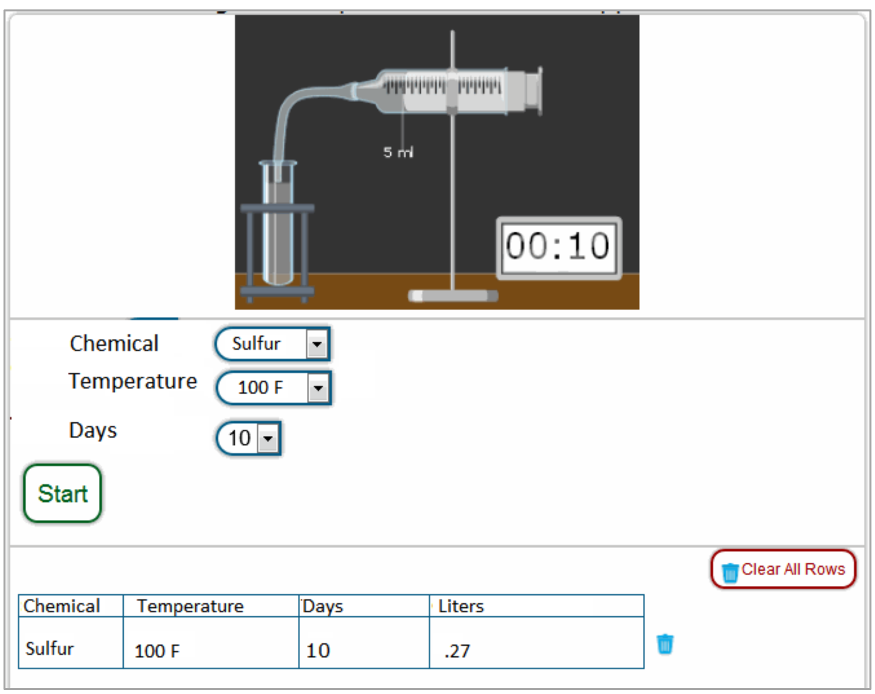
Alert: Graphic Gap Match interactions do not allow you to enable Snap-to-Point or Snap-to-Grid mode. You cannot pre-place image or text objects in the grid area with Graphic Gap Match Interactions.

Basically, graphic gap match and hotspot are dedicated interactions that don’t support all the features of a grid. The trade-off here is:

- Graphic gap match and hotspot interactions are rendered differently (more simplistically)
- In some ways, graphic gap match and hotspot are easier to author and maintain
- Grid interactions need to use the “grid rubric tool,” which is quite complicated

Simulation Interaction Editor

The Simulation Interaction Editor allows you to create content for Simulation interactions only. Simulation interactions consist of an animation tool, a set of input tools, and an output table. Students select parameters from the input tools to influence the animation. After the animation runs, the simulation results appear in the output table. Students can run multiple trials with different parameters to insert additional rows into this table.



Appendix 2-J

Shared Science Assessment Item Bank

Shared Science Assessment Item Bank

Table J-1. Spring 2023 Shared Science Assessment Operational and Field-Test Item Bank by Performance Expectation, Elementary School

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items
Earth and Space Sciences	ESS1	4-ESS1-1	2	0	14	16
		5-ESS1-1	2	2	13	17
		5-ESS1-2	7	1	14	22
	ESS2	3-ESS2-1	3	1	8	12
		3-ESS2-2	4	2	10	16
		4-ESS2-1	4	2	10	16
		4-ESS2-2	4	1	12	17
		5-ESS2-1	0	2	13	15
		5-ESS2-2	4	0	13	17
	ESS3	3-ESS3-1	4	1	9	14
		4-ESS3-1	7	1	5	13
		4-ESS3-2	9	1	12	22
		5-ESS3-1	4	1	11	16
Life Sciences	LS1	3-LS1-1	7	0	9	16
		4-LS1-1	9	1	12	22
		4-LS1-2	3	0	16	19
		5-LS1-1	3	2	14	19
	LS2	3-LS2-1	4	2	11	17
		5-LS2-1	2	1	16	19
	LS3	3-LS3-1	3	1	12	16
		3-LS3-2	4	1	8	13
	LS4	3-LS4-1	4	1	12	17
		3-LS4-2	9	1	7	17
		3-LS4-3	4	2	8	14
		3-LS4-4	6	1	8	15
Physical Sciences	PS1	5-PS1-1	5	2	11	18
		5-PS1-2	3	1	9	13

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items
		5-PS1-3	4	1	11	16
		5-PS1-4	2	2	10	14
	PS2	3-PS2-1	4	1	8	13
		3-PS2-2	5	1	7	13
		3-PS2-3	5	0	8	13
		3-PS2-4	4	0	9	13
		5-PS2-1	4	2	7	13
	PS3	4-PS3-1	4	1	14	19
		4-PS3-2	3	1	15	19
		4-PS3-3	3	1	11	15
		4-PS3-4	5	1	13	19
		5-PS3-1	4	2	9	15
	PS4	4-PS4-1	2	1	11	14
		4-PS4-2	1	0	14	15
		4-PS4-3	4	1	13	18
Total			**174**	**46**	**457**	**677**

Note. [a]Other MOU states include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming.

Table J-2. Spring 2023 Shared Science Assessment Operational and Field-Test Item Bank by Performance Expectation, Middle School

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
Earth and Space Sciences	ESS1	MS-ESS1-1	5	1	9	15
		MS-ESS1-2	2	1	8	11
		MS-ESS1-3	3	1	8	12
		MS-ESS1-4	4	2	10	16
	ESS2	MS-ESS2-1	3	1	6	10
		MS-ESS2-2	4	0	10	14
		MS-ESS2-3	4	1	8	13
		MS-ESS2-4	2	0	8	10
		MS-ESS2-5	3	1	9	13
		MS-ESS2-6	6	0	3	9
	ESS3	MS-ESS3-1	3	0	10	13
		MS-ESS3-2	4	1	8	13
		MS-ESS3-3	2	1	11	14
		MS-ESS3-4	2	1	11	14
		MS-ESS3-5	5	2	8	15
Life Sciences	LS1	MS-LS1-1	2	1	10	13
		MS-LS1-2	2	2	9	13
		MS-LS1-3	2	0	9	11
		MS-LS1-4	5	0	5	10
		MS-LS1-5	2	0	10	12
		MS-LS1-6	4	1	7	12
		MS-LS1-7	4	1	5	10
		MS-LS1-8	6	0	7	13
	LS2	MS-LS2-1	6	1	12	19
		MS-LS2-2	5	0	7	12
		MS-LS2-3	3	0	10	13
		MS-LS2-4	8	0	10	18
		MS-LS2-5	4	1	9	14
	LS3	MS-LS3-1	2	1	8	11

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
		MS-LS3-2	4	1	9	14
	LS4	MS-LS4-1	5	1	7	13
		MS-LS4-2	2	1	8	11
		MS-LS4-3	3	1	8	12
		MS-LS4-4	3	0	9	12
		MS-LS4-5	5	0	10	15
		MS-LS4-6	2	2	7	11
Physical Sciences	PS1	MS-PS1-1	3	1	7	11
		MS-PS1-2	2	1	8	11
		MS-PS1-3	5	1	6	12
		MS-PS1-4	3	0	11	14
		MS-PS1-5	2	1	10	13
		MS-PS1-6	3	0	5	8
	PS2	MS-PS2-1	2	1	8	11
		MS-PS2-2	1	1	8	10
		MS-PS2-3	2	1	7	10
		MS-PS2-4	2	2	9	13
		MS-PS2-5	1	1	13	15
	PS3	MS-PS3-1	3	1	7	11
		MS-PS3-2	2	1	8	11
		MS-PS3-3	7	0	6	13
		MS-PS3-4	3	1	7	11
		MS-PS3-5	5	1	6	12
	PS4	MS-PS4-1	3	1	7	11
		MS-PS4-2	6	1	7	14
		MS-PS4-3	2	1	9	12
Total			**188**	**44**	**452**	**684**

Note. [a]Other MOU states include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming. [b]Count excludes eight middle school MOU items that do not align to the NGSS.

Table J-3. Spring 2023 Shared Science Assessment Operational and Field-Test Item Bank by Performance Expectation, High School

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
Earth and Space Sciences	ESS1	HS-ESS1-1	2	0	4	6
		HS-ESS1-2	4	1	2	7
		HS-ESS1-3	1	1	3	5
		HS-ESS1-4	2	1	2	5
		HS-ESS1-5	2	0	4	6
		HS-ESS1-6	3	0	4	7
	ESS2	HS-ESS2-1	1	0	5	6
		HS-ESS2-2	3	1	4	8
		HS-ESS2-3	2	0	3	5
		HS-ESS2-4	2	0	5	7
		HS-ESS2-5	2	1	3	6
		HS-ESS2-6	1	0	6	7
		HS-ESS2-7	1	1	4	6
	ESS3	HS-ESS3-1	2	0	4	6
		HS-ESS3-2	1	1	4	6
		HS-ESS3-3	0	0	3	3
		HS-ESS3-4	4	0	3	7
		HS-ESS3-5	2	1	6	9
		HS-ESS3-6	4	0	3	7
Life Sciences	LS1	HS-LS1-1	3	1	6	10
		HS-LS1-2	3	1	7	11
		HS-LS1-3	0	0	5	5
		HS-LS1-4	5	0	4	9
		HS-LS1-5	2	0	7	9
		HS-LS1-6	3	0	7	10
		HS-LS1-7	3	0	6	9
	LS2	HS-LS2-1	2	0	5	7
		HS-LS2-2	2	1	7	10
		HS-LS2-3	1	0	6	7

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
		HS-LS2-4	4	1	5	10
		HS-LS2-5	3	0	4	7
		HS-LS2-6	3	0	4	7
		HS-LS2-7	4	0	7	11
		HS-LS2-8	2	0	6	8
	LS3	HS-LS3-1	1	1	7	9
		HS-LS3-2	4	1	6	11
		HS-LS3-3	3	0	5	8
	LS4	HS-LS4-1	6	1	5	12
		HS-LS4-2	2	1	4	7
		HS-LS4-3	2	1	7	10
		HS-LS4-4	2	0	8	10
		HS-LS4-5	4	0	6	10
		HS-LS4-6	2	1	3	6
Physical Sciences	PS1	HS-PS1-1	4	1	4	9
		HS-PS1-2	2	2	3	7
		HS-PS1-3	3	1	5	9
		HS-PS1-4	2	0	2	4
		HS-PS1-5	1	2	4	7
		HS-PS1-6	2	0	3	5
		HS-PS1-7	3	1	5	9
		HS-PS1-8	2	0	4	6
	PS2	HS-PS2-1	2	1	5	8
		HS-PS2-2	2	1	4	7
		HS-PS2-3	1	1	6	8
		HS-PS2-4	1	1	2	4
		HS-PS2-5	2	0	1	3
		HS-PS2-6	2	2	2	6
	PS3	HS-PS3-1	2	1	5	8
		HS-PS3-2	2	1	4	7
		HS-PS3-3	3	2	5	10
		HS-PS3-4	2	0	5	7

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Bank Items[b]
		HS-PS3-5	2	1	4	7
	PS4	HS-PS4-1	1	1	3	5
		HS-PS4-2	1	0	3	4
		HS-PS4-3	1	2	4	7
		HS-PS4-4	3	2	2	7
		HS-PS4-5	3	0	1	4
Total			**154**	**41**	**295**	**490**

Note. [a]Other MOU states include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming. [b]Count excludes one high school MOU item that does not align to the NGSS.

Appendix 2-K

Idaho Standards Achievement Test in Science Item Pool

Idaho Standards Achievement Test in Science Item Pool

Table K-1. Spring 2023 Idaho Standards Achievement Test in Science Operational and Field-Test Item Pool by Performance Expectation, Grade 5

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Item Pool
Earth and Space Sciences	ESS1	ESS1-4-1	2	0	5	7
		ESS1-5-1	1	2	5	8
		ESS1-5-2	7	1	1	9
	ESS1/2	ESS1-3-1	2	1	6	9
		ESS1-3-2	2	2	5	9
		ESS2-4-1	3	2	4	9
		ESS2-4-2	3	1	4	8
		ESS2-5-1	0	2	2	4
		ESS2-5-2	1	0	1	2
	ESS2/3	ESS2-3-1	3	1	2	6
		ESS3-4-1	5	1	2	8
		ESS3-4-2	5	1	3	9
		ESS3-5-1	3	1	2	6
Life Sciences	LS1	LS1-4-1	9	1	4	14
		LS1-4-2	1	0	8	9
		LS1-5-1	3	2	6	11
	LS1/2	LS1-3-1	4	2	7	13
		LS2-4-1	1	1	6	8
	LS2-3	LS2-3-1	2	1	4	7
		LS2-3-2	3	1	4	8
	LS2-5	LS2-5-1	2	1	3	6
		LS2-5-2	6	1	1	8
		LS2-5-3	2	2	2	6
		LS2-5-4	2	1	6	9
Physical Sciences	PS1	PS1-5-1	5	2	4	11
		PS1-5-2	2	1	4	7
		PS1-5-3	3	1	1	5
		PS1-5-4	1	2	4	7
	PS1/2	PS1-3-1	3	1	3	7
		PS1-3-2	4	1	1	6
		PS1-3-3	3	0	4	7
		PS1-3-4	1	0	5	6
		PS2-5-1	2	2	3	7
	PS1/3	PS1-4-1	4	1	6	11
		PS1-4-2	3	1	3	7
		PS1-4-3	2	1	8	11
		PS1-4-4	4	1	6	11
		PS3-5-1	3	2	4	9
	PS2	PS2-4-1	1	1	6	8
		PS2-4-2	1	0	6	7
		PS2-4-3	2	1	5	8
Total			**116**	**46**	**166**	**328**

[a]MOU state items administered include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming.

Table K-2. Spring 2023 Idaho Standards Achievement Test in Science Operational and Field-Test Item Pool by Performance Expectation, Grade 8

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Item Pool
Earth and Space Sciences	ESS1	ESS1-MS-1	5	1	3	9
		ESS1-MS-2	2	1	0	3
		ESS1-MS-3	2	1	2	5
		ESS1-MS-4	3	2	4	9
	ESS2	ESS2-MS-1	3	1	4	8
		ESS2-MS-2	2	0	1	3
		ESS2-MS-3	3	1	5	9
		ESS2-MS-4	2	0	3	5
		ESS2-MS-5	2	1	3	6
		ESS2-MS-6	3	0	1	4
	ESS3	ESS3-MS-1	2	0	1	3
		ESS3-MS-2	2	1	4	7
		ESS3-MS-3	1	1	2	4
		ESS3-MS-4	2	1	1	4
		ESS3-MS-5	5	2	4	11
Life Sciences	LS1	LS1-MS-1	1	1	5	7
		LS1-MS-2	2	2	3	7
		LS1-MS-3	1	0	1	2
		LS1-MS-4	0	0	0	0
		LS1-MS-5	3	1	1	5
		LS1-MS-6	2	1	1	4
	LS2	LS2-MS-1	5	1	4	10
		LS2-MS-2	4	0	2	6
		LS2-MS-3	3	0	2	5
		LS2-MS-4	0	3	0	3
		LS2-MS-5	8	0	6	14
		LS2-MS-6	4	1	3	8
	LS3	LS3-MS-1	2	1	3	6
		LS3-MS-2	3	1	3	7
	LS4	LS4-MS-1	5	1	3	9
		LS4-MS-2	1	1	4	6
		LS4-MS-3	1	1	2	4
		LS4-MS-4	3	0	3	6
		LS4-MS-5	5	0	2	7
		LS4-MS-6	1	2	1	4
Physical Sciences	PS1	PS1-MS-1	1	1	3	5
		PS1-MS-2	2	1	3	6
		PS1-MS-3	3	1	2	6
		PS1-MS-4	1	0	4	5
		PS1-MS-5	1	1	1	3
		PS1-MS-6	2	0	2	4
	PS2	PS2-MS-1	2	1	3	6
		PS2-MS-2	1	1	4	6
		PS2-MS-3	2	1	3	6

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Item Pool
		PS2-MS-4	1	2	3	6
		PS2-MS-5	0	1	2	3
	PS3	PS3-MS-1	2	1	1	4
		PS3-MS-2	2	1	3	6
		PS3-MS-3	6	0	3	9
		PS3-MS-4	2	1	2	5
		PS3-MS-5	5	1	1	7
	PS4	PS4-MS-1	2	1	2	5
		PS4-MS-2	5	1	2	8
		PS4-MS-3	1	1	2	4
Total			**134**	**47**	**133**	**314**

Note. [a]MOU state items administered include Connecticut, Hawaii, Montana, Rhode Island, Oregon, Utah, West Virginia, and Wyoming.

Table K-3. Spring 2023 Idaho Standards Achievement Test in Science Operational and Field-Test Item Pool by Performance Expectation, Grade 11

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Item Pool[b]
Earth and Space Sciences	ESS1	ESS1-HS-1	1	0	3	4
		ESS1-HS-2	3	1	1	5
		ESS1-HS-3	1	1	2	4
		ESS1-HS-4	2	1	2	5
		ESS1-HS-5	2	0	2	4
		ESS1-HS-6	3	0	2	5
	ESS2	ESS2-HS-1	0	0	2	2
		ESS2-HS-2	2	1	4	7
		ESS2-HS-3	1	0	0	1
		ESS2-HS-4	1	0	1	2
		ESS2-HS-5	2	1	0	3
		ESS2-HS-7	1	1	1	3
	ESS3	ESS3-HS-1	2	0	3	5
		ESS3-HS-2	0	1	1	2
		ESS3-HS-3	0	0	3	3
		ESS3-HS-4	4	0	1	5
		ESS3-HS-5	2	1	2	5
		ESS3-HS-6	3	0	3	6
Life Sciences	LS1	LS1-HS-1	2	1	3	6
		LS1-HS-2	3	1	2	6
		LS1-HS-3	0	0	2	2
		LS1-HS-4	4	0	1	5
		LS1-HS-5	2	0	5	7
		LS1-HS-6	3	0	2	5
		LS1-HS-7	3	0	6	9
	LS2	LS2-HS-1	2	0	2	4
		LS2-HS-2	2	1	0	3
		LS2-HS-3	1	0	3	4
		LS2-HS-4	3	1	1	5
		LS2-HS-5	2	0	1	3
		LS2-HS-6	2	0	1	3
		LS2-HS-7	2	0	2	4
		LS2-HS-8	2	0	2	4
	LS3	LS3-HS-1	0	1	2	3
		LS3-HS-2	4	1	1	6
		LS3-HS-3	3	0	2	5
	LS4	LS4-HS-1	6	1	2	9
		LS4-HS-2	2	1	2	5
		LS4-HS-3	2	1	3	6
		LS4-HS-4	1	0	2	3
		LS4-HS-5	3	0	2	5
		LS4-HS-6	1	1	2	4
Physical Sciences	PSC1/2	PSC1-HS-1	0	1	0	1
		PSC1-HS-2	3	1	1	5

Science Discipline	Disciplinary Core Idea	Performance Expectation	ICCR Items	Idaho Items	MOU Items[a]	Total Item Pool[b]
		PSC1-HS-3	3	1	3	7
		PSC1-HS-4	1	0	2	3
		PSC1-HS-5	0	2	0	2
		PSC2-HS-1	1	2	2	5
		PSC2-HS-2	2	0	2	4
		PSC2-HS-3	1	2	1	4
		PSC2-HS-4	3	1	1	5
		PSC2-HS-5	2	0	2	4
	PSC3	PSC3-HS-1	0	1	0	1
		PSC3-HS-2	1	1	0	2
		PSC3-HS-3	0	0	1	1
		PSC3-HS-4	1	0	2	3
		PSC3-HS-5	1	0	2	3
	PSP1	PSP1-HS-1	2	1	1	4
		PSP1-HS-2	1	1	3	5
		PSP1-HS-3	1	1	2	4
		PSP1-HS-4	1	1	2	4
		PSP1-HS-5	1	0	1	2
		PSP1-HS-6	2	0	0	2
	PSP2	PSP2-HS-2	1	1	2	4
		PSP2-HS-3	0	2	0	2
		PSP2-HS-5	1	1	3	5
	PSP3	PSP3-HS-1	1	1	1	3
		PSP3-HS-2	1	0	2	3
		PSP3-HS-3	0	1	2	3
		PSP3-HS-4	2	2	1	5
		PSP3-HS-5	2	0	1	3
Total			**120**	**42**	**124**	**286**

Note. [a]MOU state items administered include Connecticut, Hawaii, Rhode Island, Oregon, West Virginia, and Wyoming. [b]The total count excludes three field-tested items intended for the interim pool.

Appendix 2-L

Adaptive Algorithm Design

TABLE OF CONTENTS

Adaptive Item Selection Algorithm

1. Introduction, Background, and Definitions

This document describes the adaptive item selection algorithm. The item selection algorithm is designed to cover a standards-based blueprint, which may include content, cognitive complexity, and item type constraints. The item selection algorithm will also include:

- the ability to customize an item pool based on access constraints and screen items that have been previously viewed or may not be accessible for a given individual;
- a mechanism for inserting embedded field-test items; and
- a mechanism for delivering “segmented” tests in which separate parts of the test are administered in a fixed order.

This document describes the algorithm and the design for its implementation for the test delivery system (TDS). The implementation builds extensively on the algorithm implemented in the Cambium Assessment, Inc (CAI)’s TDS and incorporates substantial CAI intellectual property. CAI will release the algorithm and the implementation described here under the same open-source license under which the rest of the open-source system is released.

The general approach described here is based on a highly parameterized multiple-objective utility function. The objective function includes:

- a measure of content match to the blueprint;
- a measure of overall test information; and
- measures of test information for each reporting category on the test.

We define an objective function that measures an item’s contribution to each of these objectives, weighting them to achieve the desired balance among them. Equation (1) sketches this objective function for a single item.

$$f_{ijt} = w_2 \frac{1}{\sum_{r=1}^{R} d_{rj}} \sum_{r=1}^{R} s_{rit} p_r d_{rj} + w_1 \sum_{k=1}^{K} q_k h_{1k}(v_{kijt}, V_{kit}, t_k) + w_0 h_0(u_{ijt}, U_{it}, t_0) \qquad (1)$$

where the term w represents user-supplied weights that assign relative importance to meeting each of the objectives d_{rj} indicates whether item j has the blueprint-specified feature r, and p_r is the user-supplied priority weight for feature r. The term s_{rit} is an adaptive control parameter that is described. In general, s_{rit} increases for features that have not met their designated minimum as the end of the test approaches.

The remainder of the terms represents an item's contribution to measurement precision:

- v_{kijt} is the value of item j toward reducing the measurement error for reporting category k for examinee i at selection t; and
- u_{ijt} is the value of item j in terms of reducing the overall measurement error for examinee i at selection t.

The terms U_{it} and V_{kit} represent the total information overall and on reporting category k, respectively.

The term q_k is a user-supplied priority weight associated with the precision of the score estimate for reporting category k. The terms t represent precision targets for the overall score (t_0) and each score reporting category score. The functions $h(.)$ are given by:

$$h_0(u_{ijt}, U_{it}, t_0) = \begin{cases} au_{ijt} \text{ if } U_{it} < t_0 \\ bu_{ijt} \text{ otherwise} \end{cases}$$

$$h_{1k}(v_{kijt}, V_{kit}, t_k) = \begin{cases} c_k v_{kijt} \text{ if } V_{kit} < t_k \\ d_k v_{kijt} \text{ otherwise} \end{cases}$$

Items can be selected to maximize the value of this function. This objective function can be manipulated to produce a pure, standards-free adaptive algorithm by setting w_2 to zero or a completely blueprint-driven test by setting $w_1 = w_0 = 0$. Adjusting the weights to optimize performance for a given item pool will enable users to maximize information subject to the constraint that the blueprint is virtually always met.

We note that the computations of the content values and information values generate values on very different scales, and that the scale of the content value varies as the test progresses. Therefore, we normalize both the information and content values before computing the value of Equation (1). This normalization is given by $x = \begin{cases} 1 \; if \; min = max \\ \frac{v - min}{max - min} \; otherwise \end{cases}$, where min and max represent the minimum and maximum, respectively, of the metric computed over the current set of items or item groups.

The remainder of this section describes the overall program flow, the form of the blueprint, and the various value calculations employed in the objective function. Subsequent sections describe the details of the selection algorithm.

1.1 BLUEPRINT

Each test will be described by a single blueprint for each segment of the test and will identify the order in which the segments appear. The blueprint will include:

- an indicator of whether the test is adaptive or fixed form;
- termination conditions for the segment, which are described in a subsequent section;
- a set of nested content constraints, each of which is expressed as:

  - the minimum number of items to be administered within the content category;
  - the maximum number of items to be administered within the content category;
  - an indication of whether the maximum should be deterministically enforced (a “strict” maximum);
  - a priority weight for the content category p_r;
  - an explicit indicator as to whether this content category is a reporting category; and
  - an explicit precision-priority weight (q_k) for each group identified as a reporting category.
- a set of non-nested content constraints, which are represented as:
  - a name for the collection of items meeting the constraint;
  - the minimum number of items to be administered from this group of items;
  - the maximum number of items to be administered from this group of items;
  - an indication of whether the maximum should be deterministically enforced (a “strict” maximum);
  - a priority weight for the group of items p_r;
  - an explicit indicator as to whether this named group will make up a reporting category; and
  - an explicit precision-priority weight (q_k) for each group identified as a reporting category.
  - The priority weights, p_r on the blueprint, can be used to express values in the blueprint match. Large weights on reporting categories paired with low (or zero) weights on the content categories below them may allow more flexibility to maximize information in a content category covering fewer fine-grained targets, while the reverse would mitigate toward more reliable coverage of finer-grained categories, with less content flexibility within reporting categories.

An example of a blueprint specification appears in Appendix J-1.

1.2 Content Value

Each item or item group will be characterized by its contribution to meeting the blueprint, given the items that have already been administered at any point. The contribution is based on the presence or absence of features specified in the blueprint and denoted by the term d in Equation (1). This section describes the computation of the content value.

1.2.1 Content Value for Single Items

For each constraint appearing in the blueprint (r), an item i either does or does not have the characteristic described by the constraint. For example, a constraint might require a minimum of four and a maximum of six algebra items. An item measuring algebra has the described characteristic, and an item measuring geometry, but algebra does not. To capture this constraint, we define the following:

- d_j is a feature vector in which the elements are d_{rj}, summarizing item j's contribution to meeting the blueprint. This feature vector includes content categories such as claims and targets as well as other features of the blueprint, such as Depth of Knowledge (DOK) and item type.
- S_{it} is a diagonal matrix, the diagonal elements of which are the adaptive control parameters s_{rit}.
- p is the vector containing the user-supplied priority weights p_r.

The scalar content value for an item is given by $C_{ijt} = d_j^{'} S_{it} p$.

Letting z_{rit} represent the number of items with feature r administered to student i by iteration t, the value of the adaptive control parameters is:

$$s_{rit} = \begin{cases} m_{it}\left(2 - \frac{z_{rit}}{Min_r}\right) & if\ z_r < Min_r \\ 1 - \frac{z_{rit} - Min_r}{Max_r - Min_r} & if\ Min_r < z_{rit} < Max_r \\ (Max_r - z_{rit}) - 1 & if\ Max_r \leq z_{rit} \end{cases}$$

The blueprint defines the minimum (Min_r) and maximum (Max_r) number of items to be administered with each characteristic (r).

The term $m_{it} = \frac{T}{T-t}$ where T is the total test length. This has the effect of increasing the algorithm's preference for items that have not yet met their minimums as the end of the test nears and the opportunities to meet the minimum diminish.

This increases the likelihood of selecting items for content that has not met its minimum as the opportunities to do so are used up. The value s is highest for items with content that has not met its minimum, declines for items representing content for which the minimum number of items has been reached but the maximum has not, and turns negative for items representing content that has met the maximum.

1.2.2 Content Value for Sets of Items

Calculation of the content value of sets of items is complicated by two factors:

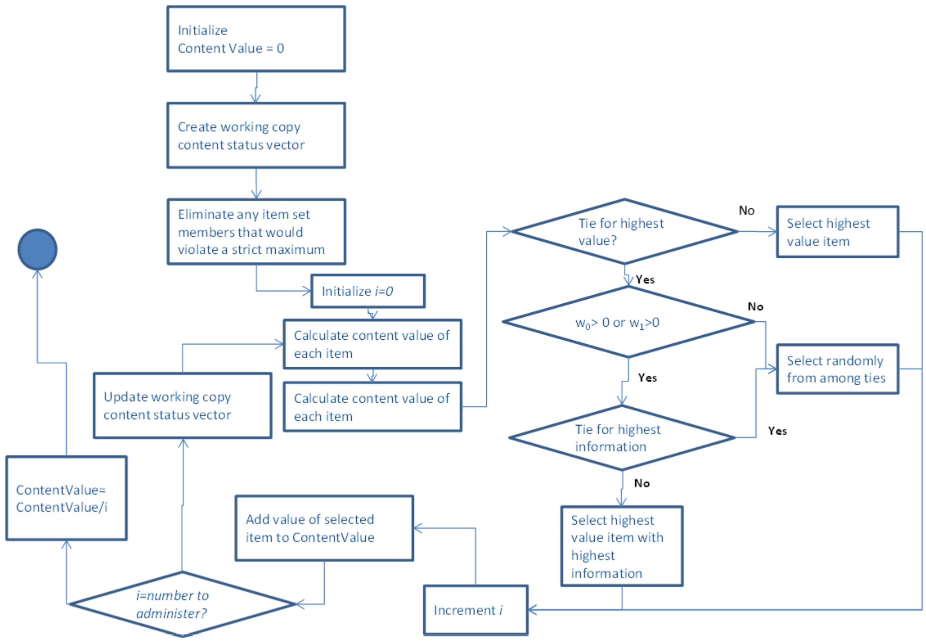
1. The desire to allow more items to be developed for each set and to have the most advantageous set of items administered.
2. The design objective of characterizing the information contribution of a set of items as the expected information over the working theta distribution for the examinee.

The former objective is believed to enhance the ability to satisfy highly constrained blueprints while still adapting to obtain good measurement for a broad range of students. The latter arises from the recognition that English Language Arts (ELA) tests will select one set of items at a time, without an opportunity to adapt once the passage has been selected.

The general approach involves successive selection of the highest content value item in the set until the indicated number of items in the set have been selected. Because the content value of an item changes with each selection, a temporary copy of the already-administered content vector for the examinee is updated with each selection such that subsequent selections reflect the items selected in previous iterations.

Exhibit A on the following page presents a flowchart for this calculation. Readers will note the check to determine whether $w_0 > 0$ or $w_1 > 0$. These weights, defined with Equation (1), identify the user-supplied importance of information optimization relative to blueprint optimization. In cases such as independent field tests, this weight may be set to zero, as it may not be desirable to make item administration dependent on the match to student performance. In more typical adaptive cases where item statistics will not be recalculated, favoring more informative items is generally better. The final measure of content value for the set of selected set of items is divided by the number of items selected to avoid a bias toward selection of sets with more items.

Exhibit A. Content Value Calculation for Item Sets



1.3 Information Value

Each item or item group also has value in terms of maximizing information, both overall and on reporting categories.

1.3.1 Individual Information Value

The information value associated with an item will be an approximation of information. The system will be designed to use generalized Item Response Theory (IRT) models; however, it will treat all items as though they offer equal measurement precision. This is the assumption made by the Rasch model, but in more general models, items known to offer better measurement are given preference by many algorithms. Subsequent algorithms are then required to control the exposure of the items that measure best. Ignoring the differences in slopes serves to eliminate this bias and help equalize exposure.

1.3.2 Binary Items

The approximate information value of a binary item will be characterized as $I_j(\theta) = p_j(\theta)(1 - p_j(\theta))$, where the slope parameters are artificially replaced with a constant.

1.3.3 Polytomous Items

In terms of information, the best polytomous item in the pool is the one that maximizes the expected information, $I_j(\theta)$. Formally, $I_j(\theta) > I_k(\theta)$ for all items $k \neq j$. The true value θ, however, remains unknown and is accessed only through an estimate, $\hat{\theta} \sim N(\bar{\theta}, \sigma_\theta)$. By definition of an expectation, the expected information $I_j(\theta) = \int I_j(t) f(t|\bar{\theta}, \sigma_\theta) dt$.

The intuition behind this result is illustrated in Exhibit B. In Exhibit B, each panel graphs the distribution of the estimate of θ for an examinee. The top panel assumes a polytomous item in which one step threshold (A1) matches the mean of the θ estimate distribution. In the bottom panel, neither step threshold matches the mean of the θ estimate distribution. The shaded area in each panel indicates the region in which the hypothetical item depicted in the panel provides more information. We see that approximately 2/3 of the probability density function is shaded in the lower panel, while the item depicted in the upper panel dominates in only about 1/3 of the cases. In this example, the item depicted in the lower panel has a much greater probability of maximizing the information from the item, despite the fact that the item in the upper panel has a threshold exactly matching the mean of the estimate distribution and the item in the lower panel does not.

Exhibit B. Two Example Items, with the Shaded Region Showing the Probability that the Item Maximizes Information for the Examinee Depicted

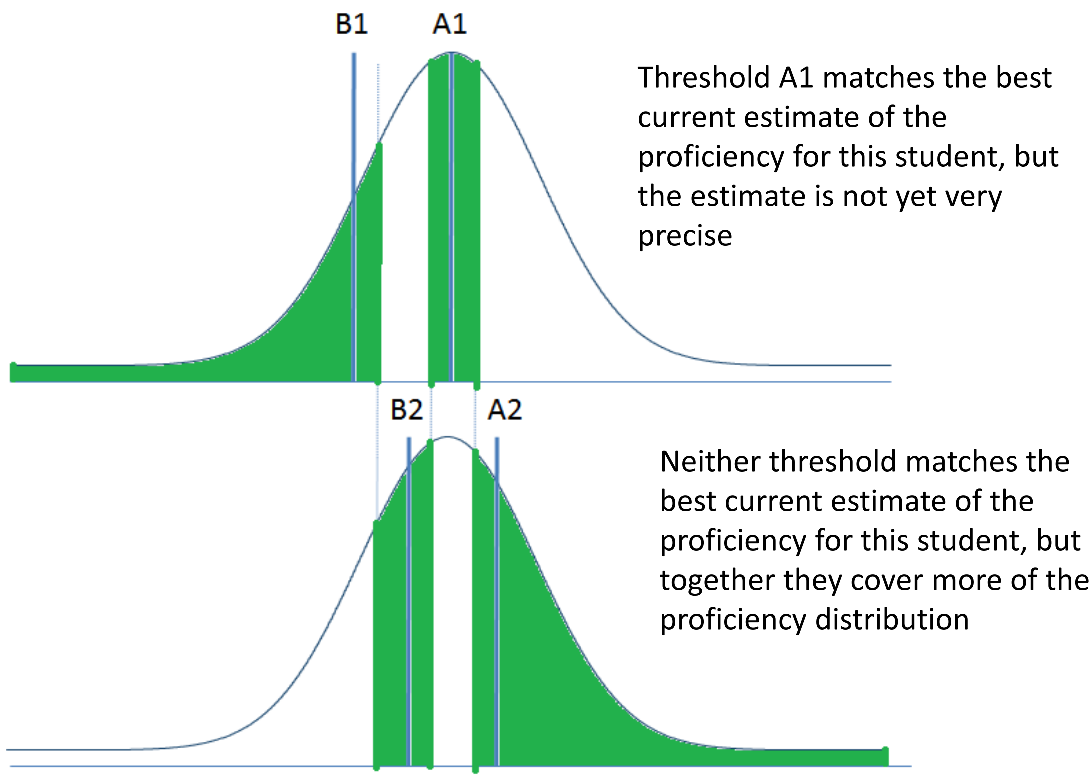
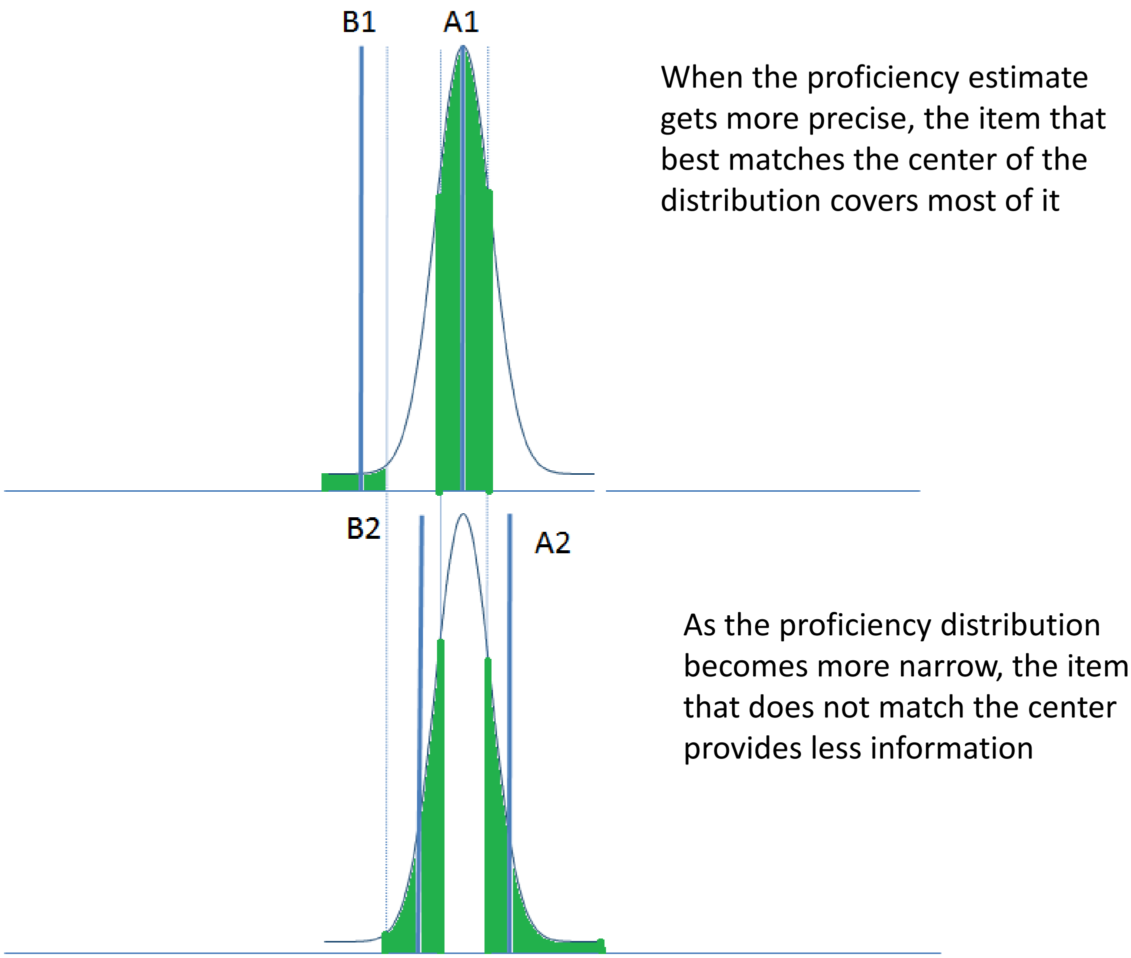


Exhibit C on the following page shows what happens to information as the estimate of this student's proficiency becomes more precise (later in the test). In this case, the item depicted in the top panel maximizes information about 65 to70 percent of the time, compared to about 30 to 35 percent for the item depicted in the lower panel. These are the same items depicted in the Exhibit B, but in this case, we are considering information for a student with a more precise current proficiency estimate.

Exhibit C. Two Example Items, with the Shaded Region Showing the Probability that the Item Maximizes Information for the Examinee Depicted



The approximate information value of polytomous items will be characterized as the expected information, specifically $E[I_j(\theta)|m_i, s_i] = \int \sum_{k=1}^{K} I_{jk}(t)\, p_j(k|t)\phi(t; m_i, s_i)dt$, where $I_{jk}(t)$ represents the information at t of response k to item j, $p_j(k|t)$ is the probability of response k to item j (artificially holding slope constant), given proficiency t, $\phi(.)$ represents the normal probability density function, and m_i and s_i represent the mean and standard deviation of examinee i's current estimated proficiency distribution.

We propose to use Gauss-Hermite quadrature with a small number of quadrature points (approximately five). Experiments show that we can complete this calculation for 1,000 items in fewer than 5 milliseconds, making it computationally reasonable.

As with the binary items, we propose to ignore the slope parameters to even exposure and avoid a bias toward the items with better measurement.

1.3.4 Item Group Information Value

Item groups differ from individual items in that a set of items will be selected for administration. Therefore, the goal is to maximize information across the working theta distribution. As with the polytomous items, we propose to use Gauss-Hermite quadrature to estimate the expected information of the item group.

In the case of multiple-item groups

$$E\left[I_g(\theta)|m_i, s_i\right] = \frac{1}{J_g}\int \sum_{j=1}^{J_g} I_{g(j)}(t)\,\phi(t; m_i, s_i)dt$$

Where $I_g(.)$ is the information from item group g, $I_{g(j)}$ is the information associated with item $j \in g$, for the J_g items in set g. In the case of polytomous items, we use the expected information, as described above.

2. Entry and Initialization

At startup, the system will

- create a custom item pool;
- initialize theta estimates for the overall score and each score point; and
- insert embedded field-test items.

2.1 Item Pool

At test startup, the system will generate a *custom item pool*, a string of item IDs for which the student is eligible. This item pool will include all items that

- are active in the system at test startup; and
- are not flagged as "access limited" for attributes associated with this student.

The list will be stored in ascending order of ID.

2.2 Adjust Segment Length

Custom item pools run the risk of being unable to meet segment blueprint minimums. To address this special case, the algorithm will adjust the blueprint to be consistent with the custom item pool. This capability becomes necessary when an accommodated item pool systematically excludes some content.

Let

$\boldsymbol{S}$ be the set of top-level content constraints in the hierarchical set of constraints, each consisting of the tuple (*name*, *min*, *max*, *n*);

$\boldsymbol{C}$ be the custom item pool, each element consisting of a set of content constraints $\boldsymbol{B}$;

$\boldsymbol{f}, \boldsymbol{p}$ integers represent item shortfall and pool count, respectively; and

$\boldsymbol{t}$ be the minimum required items on the segment.

For each s in $\boldsymbol{S}$, compute n as the sum of active operational items in $\boldsymbol{C}$ classified on the constraint.

$\boldsymbol{f}$ = summation over S $(min - n)$

$\boldsymbol{p}$ = summation over S (n)

if $t - f < p$, then $t = t - f$

2.3 Initialization of Starting Theta Estimates

The user will supply five pieces of information in the test configuration:

1. A default starting value if no other information is available

2. An indication whether prior scores on the same test should be used, if available
3. Optionally, the test ID of another test that can supply a starting value, along with
4. Slope and intercept parameters to adjust the scale of the value to transform it to the scale of the target test
5. A constant prior variance for use in calculation of working EAP scores

2.4 Insertion Of Embedded Field-Test Items

Each blueprint will specify

- the number of field-test items to be administered on each test;
- the first item position into which a field-test item may be inserted; and
- the last item position into which a field-test item may be inserted.

Upon startup, select randomly from among the field-test items or item sets until the system has selected the specified number of field-test items. If the items are in sets, the sets will be administered as a complete set, and this may lead to more than the specified number of items administered.

The probability of selection will be given by $p_j = \frac{\sum_{j=1}^{K} K_j}{\sum_{j=1}^{K} a_j K_j} a_j K_j \frac{m}{N_J}$, where

p_j represents the probability of selecting the item;

m is the targeted number of field-test items;

N_j is the total number of active items in the field-test pool;

K_j is the number of items in item set j; and

a_j is a user-supplied weight associated with each item (or item set) to adjust the relative probability of selection.

The a_j variables are included to allow for operational cases in which some items must complete field testing sooner or enter field testing later. While using this parameter presents some statistical risk, not doing so poses operational risks.

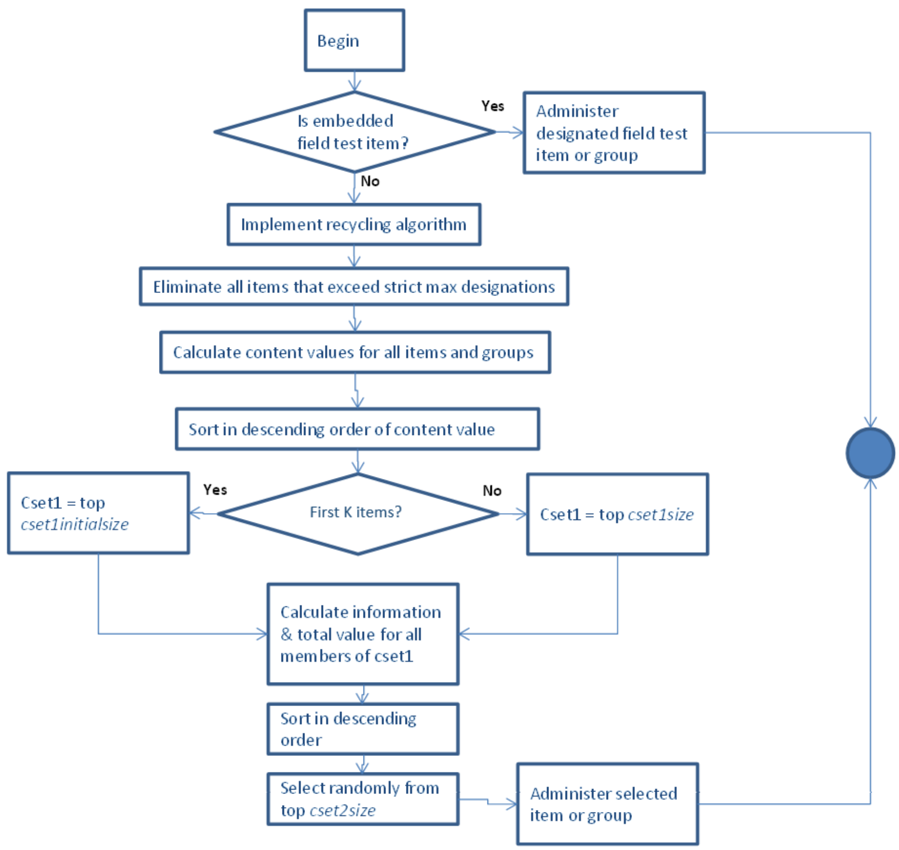
For each item set, generate a uniform random number r_j on the interval $\{0,1\}$. Sort the items in ascending order by $\frac{r_j}{p_j}$. Sequentially select items, summing the number of items in the set. Stop the selection of field-test items once $FTNMin \leq m \leq FTNMax = \sum_{j=0} K_j$.

Next, each item is assigned to a position on the test. To do so, select a starting position within $f - FTMax - FTMin$ positions from $FTMin$, where $FTMax$ is the maximum allowable position for field-test items and $FTMin$ is the minimum allowable position for field-test items. $FTNMin$ and $FTNMax$ refer to the minimum and maximum number of field-test items, respectively. Distribute the items evenly within these positions.

3. ITEM SELECTION

Exhibit D summarizes the item selection process. If the item position has been designated for a field-test item, administer that item. Otherwise, the adaptive algorithm kicks in.

Exhibit D. Summary of Item Selection Process



This approach is a "content first" approach designed to optimize match to blueprint. An alternative, "information first" approach, is possible. Under an information first approach, all items within a specified information range would be selected as the first set of candidates, and subsequent selection within that set would be based, in part, on content considerations. The engine is being designed so that future development could build such an algorithm using many of the calculations already available.

3.1 TRIMMING THE CUSTOM ITEM POOL

At each item selection, the active item pool is modified in four steps:

1. The custom item pool is intersected with the active item pool, resulting in a custom active item pool.
2. Items already administered on this test are removed from the custom active item pool.

3. Items that have been administered on prior tests are tentatively removed (see Section 3.2, Recycling Algorithm).
4. Items that measure content that has already exceeded a strict maximum are tentatively removed from the pool, removing entire sets containing items that meet this criterion.

3.2 RECYCLING ALGORITHM

When students are offered multiple opportunities to test, or when prior tests have been started and invalidated, students will have seen some of the items in the pool. The trimming of the item pool eliminates these items from the pool. It is possible that in such situations, the pool may no longer contain enough items to meet the blueprint.

Hence, items that have been seen on previous administrations may be returned to the pool. If there are not enough items remaining in the pool, the algorithm will recycle items (or item groups) with the required characteristic that is found in insufficient numbers. Working from the least recently administered group, items (or item groups) are reintroduced into the pool until the number of items with the required characteristics meets the minimum requirement. When item groups are recycled, the entire group is recycled rather than an individual item. Items administered on the current test are never recycled.

3.3 ADAPTIVE ITEM SELECTION

Selection of items will follow a common logic, whether the selection is for a single item or an item group. Item selection will proceed in the following three steps:

1. Select Candidate Set 1 (*cset1*).
   a. Calculate the content value of each item or item group.
   b. Sort the item groups in descending order of content value.
   c. Select the top *cset1size*, a user-supplied value that may vary by test.
2. Select Candidate Set 2 (*cset2*).
   a. Calculate the information values for each item group in *cset1*.
   b. Calculate the overall value of each item group in *cset1* as defined in Equation (1).
   c. Sort *cset2* in descending order of value.
   d. Select the top *cset2size* item groups, where *cset2size* is a user-supplied value that may vary by test.
3. Select the item or item group to be administered.
   a. Select randomly from *cset2* with uniform probability.

Note that a "pure adaptive" test, without regard to content constraints, can be achieved by setting *cset1size* to the size of the item pool and w_2, the weight associated with meeting content constraints in Equation (1), to zero. Similarly, linear on-the-fly tests can be constructed by setting w_0 and w_1 to zero.

3.4 Selection of The Initial Item

Selection of the initial item can affect item exposure. At the start of the test, all tests have no content already administered, so the items and item groups have the same content value for all examinees. In general, it is a good idea to spread the initial item selection over a wider range of content values. Therefore, we define an additional user-settable value, *cset1initialsize*, which is the size of Candidate Set 1 on the first K items only, where K is the number of reporting categories. Similarly, we define *cset2initialisize*.

3.5 Exposure Control

This algorithm uses randomization to control exposure and offers several parameters that can be adjusted to control the tradeoff between optimal item allocation and exposure control. The primary mechanism for controlling exposure is the random selection from $CSET2$, the set of items or item groups that best meet the content and information criteria. These represent the "top k" items, where k can be set. Larger values of k provide more exposure control at the expense of optional selection.

In addition to this mechanism, we avoid a bias toward items with higher measurement precision by treating all items as though they measured with equal precision by ignoring variation in the slope parameter. This has the effect of randomizing over items with differing slope parameters. Without this step, it would be necessary to have other *post hoc* explicit controls to avoid the overexposure of items with higher slope parameters, an approach that could lead to different test characteristics over the course of the testing window.

4. Termination

The algorithm will have configurable termination conditions. These may include

- administering a minimum number of items in each reporting category and overall;
- achieving a target level of precision on the overall test score;
- achieving a target level of precision on all reporting categories; and
- achieving a score insufficiently distant from a specified score with sufficient precision (e.g., less than two standard errors below proficient). Cambium Assessment, Inc (CAI) envisions this being used in conjunction with other termination conditions to allow very high or very low achieving students to continue on to a segment that contains items from adjacent grades but barring other students from those segments.

We will define four user-defined flags indicating whether each of these is to be considered in the termination conditions (*TermCount*, *TermOverall*, *TermReporting*, *TermTooClose*). A fifth user-supplied value will indicate whether these are taken in conjunction or if satisfaction of any one of them will suffice (*TermAnd*). Reaching the minimum number of items is always a necessary condition for termination.

In addition, two conditions will each individually and independently cause termination of the test:

1. Administering the maximum number of items specified in the blueprint
2. Having no items in the pool left to administer

Appendix 1. Definitions of User-Settable Parameters

This appendix summarizes the user-settable parameters in the adaptive algorithm.

Parameter Name	Description	Entity Referred to by Subscript Index
w_0	Priority weight associated with overall information	N/A
w_1	Priority weight associated with reporting category information	N/A
w_2	Priority weight associated with match to blueprint	N/A
q_k	Priority weight associated with a specific reporting category	reporting categories
p_r	Priority weight associated with a feature specified in the blueprint (These inputs appear as a component of the blueprint.)	features specified in the blueprint
a	Parameter of the function $h(.)$ that controls the overall information weight when the information target has not yet been hit	N/A
b	Parameter of the function $h(.)$ that controls the overall information weight after the information target has been hit	N/A
c_k	Parameter of the function $h(.)$ that controls the information weight when the information target has not yet been hit for reporting category k	reporting categories
d_k	Parameter of the function $h(.)$ that controls the information weight after the information target has been hit for reporting category k	reporting categories
cset1size	Size of candidate pool based on contribution to blueprint match	N/A
cset1initialsize	Size of candidate pool based on contribution to blueprint match for the first K items or item sets selected	N/A
cset2size	Size of final candidate pool from which to select randomly	N/A
cset2initialsize	Size of candidate pool based on contribution to blueprint match and information for the first item or item set selected	
t_0	Target information for the overall test	N/A
t_k	Target information for reporting categories	reporting categories
startTheta	A default starting value if no other information is available	N/A
startPrevious	An indication of whether previous scores on the same test should be used, if available	N/A
startOther	The test ID of another test that can supply a starting value, along with startOtherSlope	N/A
startOtherSlope	Slope parameter to adjust the scale of the value to transform it to the scale of the target test	N/A

Parameter Name	Description	Entity Referred to by Subscript Index
startOtherInt	Intercept parameter to adjust the scale of the value to transform it to the scale of the target test	N/A
$FTMin$	Minimum position in which field-test items are allowed	N/A
$FTMax$	Maximum position in which field-test items are allowed	N/A
$FTNMin$	Target minimum number of field-test items	N/A
$FTNMax$	Target maximum number of field-test items	N/A
a_j	Weight adjustment for individual embedded field-test items used to increase or decrease their probability of selection	field-test items
AdaptiveCut	The overall score cutscore, usually proficiency, used in consideration of *TermTooClose*	
TooCloseSEs	The number of standard errors below which the difference is considered "too close" to the adaptive cut to proceed. In general, this will signal proceeding to a final segment that contains off-grade items.	
TermOverall	Flag indicating whether to use the overall information target as a termination criterion	N/A
TermReporting	Flag to indicate whether to use reporting category information target as a termination criterion	N/A
TermCount	Flag to indicate whether to use minimum test size as a termination condition	N/A
TermTooClose	Terminate if you are not sufficiently distant from the specified adaptive cut	
TermAnd	Flag to indicate whether the other termination conditions are to be taken separately or conjunctively	N/A

APPENDIX 2. SUPPORTING DATA STRUCTURES

Cambium Assessment, Inc (CAI) Cautions and Caveats

- Use of standard error termination conditions will likely cause inconsistencies between the blueprint content specifications, and the information criteria will cause unpredictable results, likely leading to failures to meet blueprint requirements.
- The field-test positioning algorithm outlined here is very simple and will lead to deterministic placement of field-test items.

ADDENDUM. ADJUSTMENTS TO THE USE OF ITEM CLUSTERS

Cambium Assessment, Inc (CAI) adjusted the adaptive algorithm to the use of item clusters as follows:

- Using marginal maximum likelihood estimator (MMLE) to update proficiency estimates, marginalizing out cluster effects.
- Normalizing the information by the number of assertions within an item, to avoid over-selection of item clusters and stand-alone items with more assertions.