Strengthening Claims-based Interpretations and Uses of Local and Large-scale Science Assessment Scores (SCILLSS)

A Guide to Develop Classroom-based Next Generation Science Standards Assessment Tasks: A Principled-design Approach

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Introduction

Meeting the challenges and responding to advancements in technology inherent in the 21st century require that students be educated and assessed in new ways in science. Science education goals must engage K-12 students as scientists and engineers in the classroom. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (*Framework*; National Research Council [NRC], 2012) provides a foundation for the three-dimensional science learning articulated in the Performance Expectations (PEs) of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). The PE statements describe what students should be able to do after receiving instruction. The *Framework* expresses a vision of science education that requires students to operate at the nexus of three dimensions of learning: Science and Engineering Practices (SEPs), Disciplinary Core Ideas (DCIs), and Crosscutting Concepts (CCCs). This is a new model for K-12 science education designed to deepen students' understanding of the DCIs and applications of SEPs and CCCs to investigate and explain phenomena and to design and refine solutions to problems.

The guide assumes that educators are already familiar with how to read a NGSS standards page. Educators should also be familiar with the conceptual shifts in the NGSS, the innovations addressed in the NGSS, and research on how students learn science. For related information, refer to the section, New Science Standards: The NGSS, in this guide.

Purpose and Use

This guide describes a replicable principled-design approach and tools (i.e., fillable templates) based on evidence-centered assessment design (ECD) (Almond, Steinberg, & Mislevy, 2002; Mislevy, Almond, & Lucas, 2003, Mislevy & Haertel, 2006) for use by educational stakeholders to develop classroom-based NGSS assessment tasks. This guide focuses on classroom-based NGSS assessment practices described as "embedded in an instructional sequence" using educator-developed assessment tasks that generate meaningful information about students' science learning along and during that instructional sequence. Implementing the NGSS emphasizes student experiences with natural phenomena and designing solutions to problems and the expectation that three-dimensional science learning will be enhanced and assessed. The goal is to provide principled-design and development processes, along with a set of tools, that can support educators in defining in detail the science construct(s) targeted for classroom-based assessment tasks based on the principles of the *Framework*.

The creation of classroom-based assessment tasks is challenging as it presses against traditional ways of measuring student learning. Understanding and employing a principled-design approach can enhance educators' abilities to develop classroom-based assessment tasks that provide critical information about individual student learning. However, the tasks must do more than elicit students' declarative knowledge. They must elicit evidence related to students' integration of their knowledge of DCIs, engagement with scientific practices, and facility with building connections across ideas (CCCs) (Pellegrino, 2013). As stated by NRC, 2014:

> Assessment tasks, in turn, must be designed to provide evidence of students' ability to use practices, to apply their understanding of the crosscutting concepts, and draw on their understanding of specific disciplinary ideas, all in the context of addressing specific problems. (p. 32)

This guide begins with a description of the NGSS followed by an explanation of the role of classroom-based assessment tasks administered during instruction. The sections that follow provide an overview of a principled-design approach that establishes processes and related tools to be utilized by educators to develop classroom-based NGSS assessment tasks. The first tool requires educators to consider the question, "What ideas and skills are associated with a PE?" It sets a meaningful stage for determining the knowledge, skills, and abilities (KSAs) needed to translate the NGSS into pedagogy (i.e., the method and practice of teaching) and classroom-based assessment tasks. The second tool requires educators to address, "How will classroom-based assessments need to be developed to help educators gauge students' progress towards achieving the NGSS PE?" This is accomplished in the tool as it defines components of an assessment task that educators determine by asking, "What constitutes evidence of three-dimensional science student learning, and how can I develop assessment task specifications that will illicit what students have indeed learned?"

To illustrate the application of this principled-design approach and the development and use of the tools, a grade 5 example classroom-based assessment task and rubric are included. This example illustrates concrete steps to create three-dimensional classroom-based assessments when educators are planning for assessment of student learning during instructional sequences in their classrooms. Further exemplars for grades 5, 8, and 11 are provided in appendices A through E. The exemplars provide additional examples of how educators may begin to address the challenge of implementing conceptual shifts in the NGSS to improve science education by making changes to their instruction and assessment practices that will bring about science learning for the 21st century.

In the conclusion, it is recognized that educators will need professional development opportunities to understand how to use and apply the principled-design and development processes, along with the tools herein, during an instructional sequence in the classroom. Creating opportunities for educators on models of how three-dimensional tasks can be used formatively in the classroom is instrumental for effective use of classroom-based assessment tasks.

New Science Standards: The NGSS

The NGSS are described as "robust" and "forward-looking" standards that all states can use to guide teaching and learning.[1] Based on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, the NGSS are intended to reflect a new vision for American science education. That vision is new in that students must be engaged at the nexus of the three dimensions: 1) SEPs, 2) CCCs, and 3) DCIs.

Presented as PEs, the standards state what students are expected to be able to do to demonstrate their science knowledge and understanding after instruction to investigate complex ideas, make sense of phenomena, and solve real-world problems (i.e., knowledge in use). The PEs focus on understanding and application as opposed to memorization of facts and procedural skills.

The NGSS do not dictate curriculum materials and instructional practices. Educators can use the NGSS as goals for instruction to develop lessons within an instructional sequence and plan investigations activities to promote a logical progression of three-dimensional science learning within and across grades. Building on the knowledge and skills gained from each grade, from elementary through high

[1] Understanding the Standards. (n.d.). Retrieved from https://www.nextgenscience.org/understanding-standards/understanding-standards.

school, students have multiple opportunities to revisit and expand their understanding of all three dimensions by the end of high school.

The PEs integrate three dimensions of science learning: SEPs, DCIs, and CCCs. The SEPS are used by students to demonstrate understanding of the DCIs and CCCs. The SEPs connect science with mathematics, English language arts, and other disciplines through meaningful and substantive overlapping skills and knowledge. The DCIs are the focused, limited set of science ideas necessary for all students to achieve scientific literacy. The CCCs are used to organize and make sense of the DCIs. They serve as tools that bridge domain boundaries and deepen understanding of content. The DCIs, SEPs, and CCCs each build coherently K-12 to allow for deeper understanding of science concepts. Below is an example for grade 5 physical sciences, specifically Structure and Properties of Matter.

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.

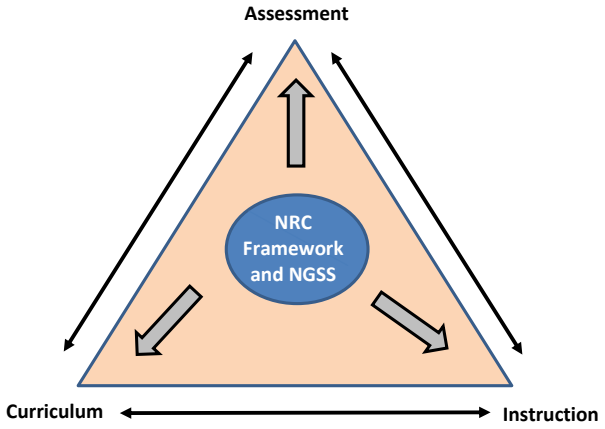
This PE first presents a SEP: *Developing and Using Models*. Second, it presents a DCI: *Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means*. Finally, it includes a CCC: *Scale, Proportion, and Quantity*.

The Role of Classroom-based Assessment of Three-dimensional Science Learning

Understanding the purposes and uses of multiple forms of science assessment (e.g., formative, interim, and summative) found within a well-designed assessment system share a common goal—evaluation of student learning in relation to NGSS-aligned goals and expectations. As with all forms of assessments, when classroom-based assessments are well-designed and are equitable, accessible, and relevant for the widest range of students (Achieve, 2018), performance on these assessments has the potential to be used by educators to make 1) accurate inferences about students' KSAs; 2) monitor student progress; and 3) inform educator actions with respect to adjustments in the design and delivery of instruction. Classroom-based assessments designed to achieve these outcomes must address equity and accessibility for all students including English Learners (ELs) and students who receive special education services (STEM Teaching Tools, 2014-2019). What is being measured must be relevant to all students, presented in meaningful, relatable contexts, and be designed and presented in ways that allows students to demonstrate what they know and can do (e.g., promotes engagement, provides a range of presentation formats, allows for different ways of student responding (Universal design for learning (UDL)). The classroom-based tasks should minimize unnecessary or confusing language and overly complex sentence structures. In addition, the classroom-based tasks should include relevant vocabulary that has been taught and used during investigations and science learning.

Over time, the goal is that student competence and expertise develop and increase in sophistication as the product of coherent systems of curriculum, instruction, and assessment (Pellegrino, 2016). It is not intended that assessment stands alone. Instead, assessment is one of three central components (see Exhibit 1), which are linked in a coherent system (Pellegrino, 2010). For this guide, the goals of instruction are outlined by the NGSS PEs, the curriculum, whether developed or purchased, defines how that content is delivered, and the classroom-based assessments measure the outcomes of teaching and learning and attainment of the goals of instruction by students. To maximize student engagement and interest in science investigations by all students, educators can employ a pedagogical strategy in which relevance and student experiences are central. Educators can consider students' interests and locally-relevant issues to inform the selection and development of science and engineering investigations. These investigations should be relevant to students' lives and make clear how they can apply new learning to improve their lives and the lives of the larger community—beyond the classroom.

Exhibit 1. Illustration of the Interconnections Among Curriculum, Instruction, and Assessment[2]



Based on careful observation, questioning, and monitoring of students, classroom-based three-dimensional science assessments can be developed and embedded at a point within a sequence of instruction within a unit, after single or multiple units of instruction, or at a "mid-term" point. As teaching and learning opportunities occur, an educator is in the driver's seat and must determine when a "check" is necessary on student acquisition and application of the taught KSAs associated with a PE(s) or an aspect of a PE. Assessment of that learning requires educators to have a deep understanding of the multi-dimensional aspects of the PEs (Unpacking Tool), which form the basis of the instructional sequence. Educators can then create three-dimensional assessment tasks (Task Specifications Tool) that require students to revisit, extend, and apply their learning. These tasks must allow students to transfer the knowledge acquired during instruction and apply it to assessment tasks in a new context with related phenomena or design problems.

The purpose of the tools is to develop classroom-based assessment tasks with a scoring rubric. Using both tools in relation to the instructional sequence, educators begin to develop classroom-based assessments that support their "evaluation" of their instructional prowess. Classroom-based assessments provide evidence (observations, behaviors, or performances) that when evaluated by rubrics reveals what students have learned as a result of NGSS-aligned instruction. Through the intentional development of assessment tasks based on a principled-design approach, educators can answer, "Does the assessment evidence show a more or less sophisticated understanding by each student of what has been taught?" and, "When I aggregate the evidence, what do I know about the understanding of my class as a whole?"

Overview of a Principled-design Approach to Develop Classroom-based NGSS Assessment Tasks

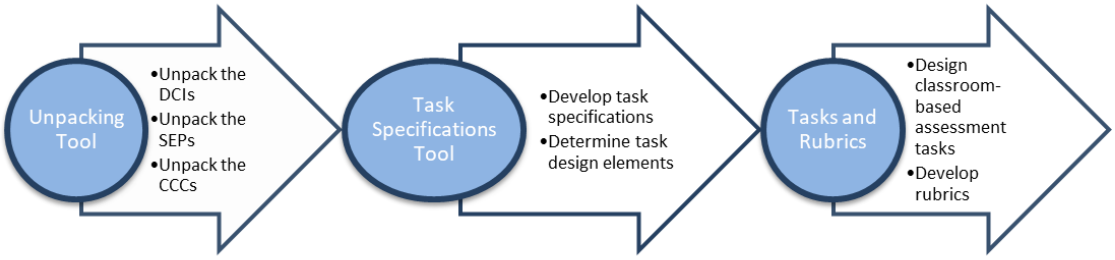
Traditional assessment strategies may not yield enough evidence of students' abilities to use scientific practice, think critically, and communicate ideas as intended by the *Framework* and the NGSS. For teachers to effectively implement assessment as part of their pedagogy, they need tools for creating

[2] Modified from Pellegrino, J.W. (2010). The design of an assessment system for the race to the top: A learning sciences perspective on issues of growth and measurement. In P. Forgione & N. Doorey (Eds.), *Exploratory Seminar: Measurement Challenges Within the Race to the Top Agenda*. Princeton, NJ: Center for K–12 Assessment & Performance Management, Educational Testing Service.

tasks and collecting and scoring student performance. Use of a principled-design approach to develop classroom-based NGSS-aligned assessment tasks can ensure that the evidence of student learning that is collected and evaluated is consistent with the KSAs represented by the PEs and the intended purpose of the assessment. Using these tools support educators in the creation of assessment tasks and scoring rubrics that support more complex assessments (i.e., multi-dimensional science assessment tasks).

This approach includes two tools that build toward task and rubric construction: 1) unpacking the three dimensions within a NGSS PE to understand and identify assessable components (Harris, Krajcik, Pellegrino, & McElhaney, 2016); and 2) identifying specifications to design assessment tasks (see Exhibit 2). The principled-design approach allows for both the Unpacking the Dimensions Tool and the Task Specifications Tool to be flexible enough for use in designing instruction and assessments and be reusable in the sense of designing multiple assessment tasks to address aspect(s) of a PE. The Task Specifications Tool assists educators in planning the intentional design of assessment tasks, which are meant to elicit information about students' KSAs, describing the context/situation with which students interact, and specifications for the form of a student's response. In addition, it is intended that educators will "revisit" the tools and improve upon them based on their instruction and assessment experiences, increased understanding of the NGSS, purpose and use of the tools, and collaboration with other educators.

Exhibit 2. A Principled-design Process and Tools for Translating the NGSS into Classroom-based Assessment Tasks



The foundation of the principled assessment design described in this guide is the collection of observable student evidence, which demonstrates student understanding of each target of measurement (i.e., KSAs) addressed by the Unpacking Tool. The tool assists educators to make clear what determination of achievement (based on the application of a rubric) is to be made about a student that is relevant to the specific purpose of the assessment. The KSA and evidence requirements shape the design of assessment tasks for students to demonstrate what they have learned. Once identified, the characteristics of these assessment opportunities are fleshed out in the Task Specifications Tool, capable of generating multiple assessment tasks. This tool, which is the basis for task development, flows directly from the Unpacking Tool, which provides further guidance on the interpretation of the three dimensions of a PE and how they can be assessed. This is the backbone of what an educator can claim about what a student knows and can do, and the observable evidence required to support those claims.

The development of classroom-based assessment tasks that yield meaningful and interpretable information requires that educators make many decisions about the design and content of the tasks and evaluation of student responses. To ensure accurate assessment of students' knowledge, skills, and abilities, educators can enhance access and support student performance by providing multiple ways in which the assessment tasks present information and ways that students express what they know and

can do by applying principles of UDL. Educators should ask themselves the following questions when designing classroom-based assessment tasks in the context of the instructional flow of the science unit:

- What PE(s) have been selected for instruction?
- How are the three dimensions interconnected in the PE?
- What are the connections between instruction and assessment?
- How will the assessment tasks be designed to ensure accessibility by all students (i.e., stimulate interest, present information in different ways, differentiate the ways student express what they know and can do)?
- What is the observable evidence of learning a student is expected to demonstrate?
- What is the best way to collect evidence of student learning of a PE or an aspect of a PE (e.g., the work product that is the "container" for the observable evidence)?
- When should assessment tasks be administered to inform instruction?
- What are the qualities of student responses that differentiate a sophisticated from a partial understanding?
- How will I adjust instruction for individual students or groups of students based on the assessments?
- How will I know when I can proceed with instruction?

Unpacking the Dimensions of a Performance Expectation Tool

Unpacking the dimensions of each PE provides a clear focus for what is to be measured and helps educators to plan for assessment. The Unpacking Tool provides a systematic approach to unpacking a PE into its multiple components to ensure educators who are designing NGSS-aligned tasks have a clear and deep understanding of each of the dimensions represented in a PE prior to beginning task development (see Exhibit 3). *Key aspects* are the underlying concepts that support each dimension of the PE and represent knowledge necessary for understanding or investigating more complex ideas and solving problems. *Prior knowledge* refers to the background knowledge that is expected of students to develop an understanding of the SEP and DCI. The *relationships between the CCC and the SEP* is included as well. When students are performing a SEP, they are often addressing one of the CCCs. For example, the CCC *Scale, Proportion, and Quantity* is an essential consideration when deciding how to *develop a model* (SEP) to describe a phenomenon. A completed Unpacking Tool template for grade 5 is found in Exhibit 5. Unpacking the Dimensions Tool for 5-PS1-1.

Exhibit 3. Template for Unpacking Tool

Grade:
NGSS Performance Expectation:

	Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)	
Foundations	**SEP:**	**DCI:**	**CCC:**	
Key Aspects	•	•	•	
Prior Knowledge	•	•	**Relationships to SEPs**	•

A selection of resources to support unpacking the PEs to identify "Key Aspects" and "Prior Knowledge" includes the *Framework*, the NGSS, and NGSS Appendices E: Disciplinary Core Ideas, F: Science and Engineering Practices, and G: Crosscutting Concepts (i.e., progressions). Research literature on designing NGSS-aligned assessments are included in the reference section. Additional examples of completed tools for grades 5, 8, and 11 are provided in Appendix A through Appendix E of this guide.

Assessment Task Specifications Tool

Identifying the assessment tasks specifications allows educators to translate the PE-specific unpacking of the three dimensions into assessment tasks. Task specifications allow educators to determine what counts as evidence for student learning. The Task Specifications Tool is intended to help educators develop assessment tasks that allow students opportunities to call upon, transfer, and apply learning that has occurred during instruction to new challenges, much the way a scientist or engineer would, in an assessment situation.

Presented as a fillable template (see Exhibit 4), the Task Specifications Tool identifies the key components needed to develop purposeful assessment tasks. This tool is modeled after ECD design patterns (Almond, Steinberg, & Mislevy, 2002; Mislevy, Almond, & Lucas, 2003, Mislevy & Haertel, 2006). The Task Specifications Tool components serve as a set of considerations for the task writer (e.g., educator) when developing classroom-based assessment tasks.

Based on the instructional sequence and which components of the PE(s) have been taught, the educator determines *when* to assess and *what* to assess (i.e., at a point in time, the KSAs that warrant assessment to make inferences about student learning). These decisions are born out of observing students during science investigations, monitoring student-generated questions and problem-solving strategies, and when student evidence is needed to inform the direction of the instructional sequence. To create a task, the educator must define the aspect(s) of the PE to be assessed and make design choices about what information is presented to a student, how it is presented, how the examinee interacts with the tasks, and how responses are provided. The Assessment Task Specifications Tool indicates the components needed to be considered by the educator to develop a high-quality task including:

- the aspect(s) of the PE to address (i.e., the KSAs);

- the kinds of behaviors and performances that show what students should be able to do after instruction (i.e., Student Demonstration of Learning);
- the items, situations, or stimuli that will elicit evidence of student learning (i.e., Work Product); and
- the features of task situations that allow students to demonstrate the degree to which expectations have been met (i.e., Task Features).

Exhibit 4. Assessment Task Specifications Tool Overview

Element	Description
Performance Expectation	• Indicate the PE from the instructional sequence to be assessed.
Knowledge, Skills & Abilities (KSAs)	• Develop statements, which specify what is expected of students to demonstrate (i.e., KSAs) to provide evidence that they have learned one or more aspects of a PE.
Student Demonstration of Learning	• List what students should be able to do to demonstrate that they have met the KSA(s). • Define qualities of student performance that constitute student evidence.
Work Product	• Determine the "vehicles" (i.e., work products) that are intended to contain observable evidence (e.g., a model, an argument, a description, a graph, a chart).
Task Features	• List the task features from which the task writer selects to develop an assessment task. • Reference the "Clarification Statement" in the NGSS for the PE as appropriate. • Note: A single question/task may not represent all the features listed.
Aspects of an assessment task that <u>can be varied</u> to shift complexity or focus	• Allows for a range of tasks to be developed of varying complexity. • Allows for development of tasks that focus on various skills related to the PE. • Allows the task developer to match features of the task with the characteristics of students such as their interests, familiarity, and provided instruction.
Assessment Boundaries	• List information that is NOT assessed (i.e., related above grade-level ideas and skills). • Reference the "Assessment Boundary" in the NGSS for the PE as appropriate.

Assessment Task Construction: Classroom-based Assessment Tasks and Rubrics

A well-designed assessment task presents engaging, authentic, real-world contexts and phenomena of interest to a wide range of students, and calls for students to transfer and apply their knowledge in keeping with the goals of the *Framework* and the NGSS. This approach would provide a seamless transition from learning to testing. A classroom-based task measures, at a point in time determined by the educator, students' acquisition of KSAs taught during an instructional sequence. Student competency is required in order for additional, more sophisticated learning to occur in the subsequent

lessons in the instructional sequence. Developed in these ways, the classroom-based assessment tasks enable educators to get their fingers on the pulse of individual students, groups of students, and/or the entire class as to where they are in their science learning and collect evidence to ultimately inform instruction. The completion of the Unpacking Tool and the Task Specifications Tool lends itself to the development of assessment tasks to evaluate student progress in the instructional sequence.

The Classroom-based Assessment Task

A three-dimensional assessment task must elicit evidence related to students' integration of knowledge of DCIs, engagement with SEPs, and facility with building connections across ideas (CCCs) (NRC, 2012; Pellegrino, 2013). The task may necessarily be comprised of multiple items to elicit evidence that provides specific information about student understanding and competence of the three dimensions as they relate to a PE (e.g., core ideas, representing data, interpreting data, engaging in argument from evidence). The assessment task provides an indication of the student's current understanding of the selected KSAs as set forth in the Task Specifications Tool. A single item may not be sufficient to elicit evidence to allow educators to identify where students may have misunderstandings and need additional instruction. Each task includes scientifically accurate information, is aligned to three-dimensional learning, and may include standalone or a suite/series of questions to allow students to demonstrate the degree to which expectations have been met. The task may include multiple parts, questions, or prompts connected to a phenomenon or problem-solving context or event. When responding to the task, the students must clearly understand how to complete the task and what is expected to demonstrate a high level of competency.

The Rubric

A rubric defines the criteria that educators use to interpret and evaluate student evidence of learning. When developing classroom-based rubrics, the educator must consider the type of student evidence to be collected. Depending upon the intended use of classroom-based assessment tasks during an instructional sequence, the type of evidence gathered may vary from situation to situation. In addition, the educator must decide how to integrate DCIs, SEPs, and CCCs within their rubrics.

It is critical to write a rubric that includes descriptors for each question or prompt in the assessment task that describes the full range of student understanding from low to high levels of competency. In general, a high-level response is scientifically accurate, complete and coherent, and consistent with the type of student evidence expected. A low-level response may include misconceptions, is incomplete, and is not consistent with the type of evidence expected. Student responses should yield accurate inferences about students' KSAs that inform educator actions either to 1) continue with the instructional sequence as planned; or 2) adjust the design, delivery, and sequence of instruction. Instructional decisions can be made at the individual student level, for a small group of students, or at the class level.

Grade 5 Classroom-based Assessment Task Example

The SCILLSS' principled-design approach has been applied to develop an example grade 5 classroom-based assessment task and rubric. A completed Unpacking Tool and Assessment Task Specifications Tool for a grade 5 PE are integrated to design a classroom-based assessment task example including exemplar high-level responses.

Unpacking the Dimensions of a Performance Expectation Tool for 5-PS1-1

Exhibit 5 presents the unpacking of the three dimensions associated with 5-PS1-1 utilizing the Unpacking Tool. Refer to the section Unpacking the Dimensions of a Performance Expectation Tool in this guide for related information.

Exhibit 5. Unpacking the Dimensions Tool for 5-PS1-1

Grade: 5			
NGSS Performance Expectation: 5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen. [Clarification Statement: 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.] [*Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.*]			
	Science and Engineering Practices (SEP)	**Disciplinary Core Ideas (DCI)**	**Crosscutting Concepts (CCC)**
Foundations	**SEP: Developing and Using Models** Develop a model to describe phenomena.	**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.	**CCC: Scale, Proportion, and Quantity** Natural objects exist from the very small to the immensely large.
Key Aspects	• Identify components of the model. • Use a model to reason about a phenomenon. • Reason about the relationship of the different components of a model. • Select and identify relevant aspects of a situation or phenomena to include in the model.	• Everything around us (matter) is made up of particles that are too small to be seen. • Matter that cannot be seen can be detected in other ways. • Gas (air) has mass and takes up space. • Gas (air) particles, which are too small to be seen, can affect larger particles and objects. • Gas particles freely move around in space, until they hit a material that keeps them from moving further, thus trapping the gas (e.g., air inflating a basketball, an expanding balloon).	• Understand the units used to measure and compare quantities. • Describe relationships between natural objects which vary in size (very small to the immensely large). • Understanding of scale involves not only understanding systems and processes vary in size, time span, and energy, but also different mechanisms operate at different scales.
Prior Knowledge	• Knowledge that a model contains elements (observable and unobservable) that represent specific aspects of real-world phenomena • Knowledge that models are used to help explain or predict phenomena	• Matter is anything that occupies space and has mass. • Matter can change in different ways.	**Relationships to SEPs** • Models describe the scale of natural objects. • Data analysis serves to demonstrate the relative magnitude of some properties or processes. • Calculate proportions correctly and measure accurately for valid results.

Assessment Task Specifications Tool for 5-PS1-1

Exhibit 6 illustrates a completed Task Specifications Tool for 5-PS1-1. It informs the design of tasks and rubrics related to students' evaluation of the correspondence between a model and its real-world counterparts. Refer to the section Assessment Task Specifications Tool in this guide for more information.

Exhibit 6. Assessment Task Specifications Tool for 5-PS1-1

Element	Description
Performance Expectation	**5-PS1-1** Develop a model to describe that matter is made of particles too small to be seen.
Knowledge, Skills & Abilities (KSAs)	**KSA1:** Develop a model to describe matter. **KSA2:** Use a provided model to describe matter. **KSA3:** Use a provided model to describe that matter is made of particles too small to be seen. **KSA4**: Develop a model to describe that matter is made of particles too small to be seen.
Student Demonstration of Learning	• Model accurately represents the observable phenomena • Model accurately captures all mechanistic features of the observable phenomena • Scale of model components is relevant to various objects, systems, and processes • Model and response accurately describe the particles in the two conditions (i.e., before and after stirring) • Describes a phenomenon that includes the idea that matter is made of particles too small to be seen • Correctly identifies and describes relevant relationships between components of the model
Work Product	• Draw a model • Complete a model • Constructed-response
Task Features	• All tasks must prompt students to describe relationships between observed phenomenon or evidence and reasoning underlying the observation/evidence. • Students use scientific reasoning and process skills. • All tasks must elicit core ideas as defined in the PE. • All tasks must include elements from at least two dimensions of the NGSS.

Aspects of an assessment task that <u>can be varied</u> to shift complexity or focus	• Complexity of scientific concept(s) to be modeled
	• Function of the model:
	  ○ to explain a mechanism underlying a phenomenon;
	  ○ to predict future outcomes;
	  ○ to describe a phenomenon;
	  ○ to generate data to inform how the world works
	• The degree to which components of the model are provided
	• The model may be provided for revision or one that is created from scratch
	• Representation of model
	• What matter is being modeled

	• Use or purpose of the model • Type of model (e.g., physical/virtual) • What states of matter are represented and/or included (and how many) and if they are compared
Assessment Boundaries	• Students are not expected to know that matter is made of atoms and molecules. • Students are not expected to explain the properties of the particles. • Students are not expected to apply proportional reasoning skills (Note: should not be included, as students learn proportions in in grade 6, CCSSM[3]). • Density should not be included. • Mass and weight are not distinguished.

Task and Rubric Construction

Exhibit 7 provides an example of a classroom-based assessment task for **5-PS1-1**. Exhibit 8 and Exhibit 9 provide an exemplar high-level student response. Exhibit 10 provides a NGSS classroom-based assessment task example rubric for evaluating student work products. It is expected that educators have engaged students in investigations that led to deeper understanding of scientific concepts related to different types of matter and its properties. Refer to section Assessment Task Construction: Classroom-based Assessment Tasks and Rubrics in this guide for further information.

[3] National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics*. Washington DC: Author.

Exhibit 7. Example 5-PS1-1 Classroom-based NGSS Assessment Task

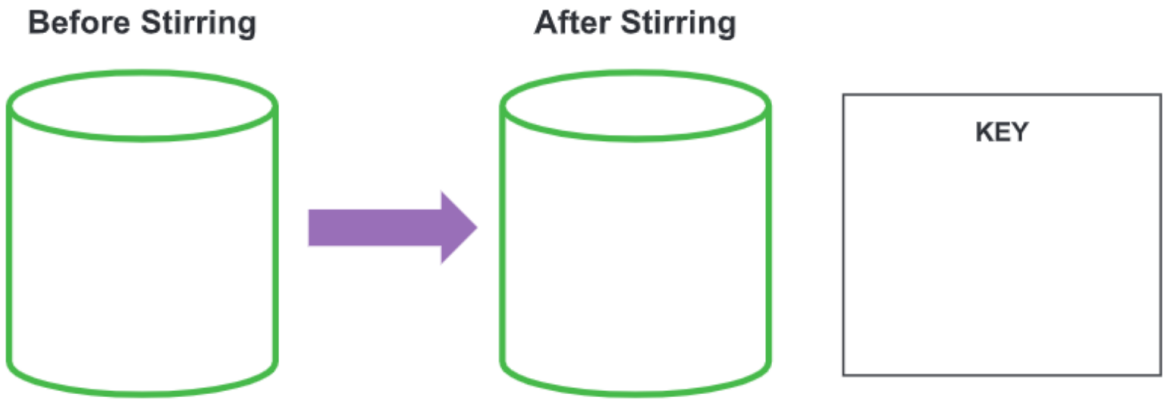
This task is about the particles of matter. Be sure to answer question 1 and question 2.

1. Jose cleaned his salt water fish tank. The water in the tank looked clear. His friend Carl visits and asks, "Why can't I see the salt in the water?" Jose creates a model to show Carl what happens to salt when stirred into water.

Complete the model below to show:

- the salt particles and water particles **before** stirring the mixture
- the salt particles and water particles **after** stirring the mixture

Be sure to complete the key to show the salt particles and water particles in both conditions of your model.



2. Describe the change to the salt particles after being stirred in the water. Be sure to use information from your model to support your explanation.

Exhibit 8. Exemplar 5-PS1-1 High-level Student Response: Question 1 Student Model

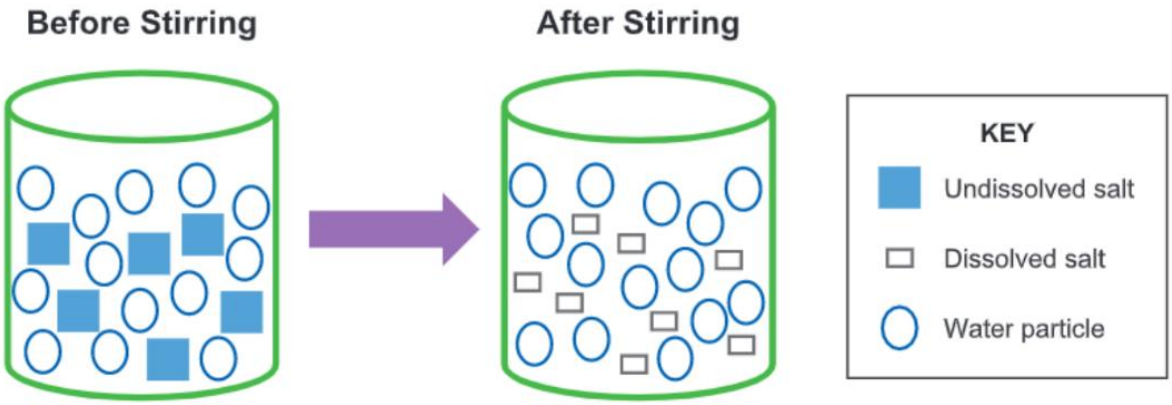


Exhibit 9. Exemplar 5-PS1-1 High-level Student Response: Question 2 Student Explanation

"The model shows that the salt particles dissolve. They break into smaller pieces after they are stirred into water. The salt particles are still in the water, but you can't see them. That's because they got so small."

Exhibit 10. 5-PS1-1 Classroom-based NGSS Assessment Task Example Rubric

Student Expectations of Learning	1	2	3
Student uses the model to describe how matter composed of tiny particles is too small to be seen.	Student develops a model that does **not** account for observable phenomena. Description is incorrect or is not provided.	Student develops a model that shows: • a flawed connection between bulk matter and particles too small to be seen (e.g., salt particles are represented at the same size under both conditions; all salt particles are clustered in one area of the container under both conditions; key is incorrect, etc.) Description is partially correct (e.g., does not refer to the scale of the dissolved salt particles).	Student develops a model that shows: • two representations each with two different bulk matter and matter too small to see (particles) • the representations correctly position and scale the particles relative to each other • the key is correct Description is correct.

Integration of the Assessment Development Tools: Design of the Task

A well-constructed assessment task generates meaningful information about students' science learning by providing students opportunities to demonstrate what and how well they have learned with respect to a PE or part of that PE through observed behaviors, work products, or performances. The educator integrates the information within and across the assessment development tools to design the tasks by considering and identifying:

- The key aspects addressed by the SEP, DCI, and CCC (Unpacking Tool);
- The elicited prior knowledge (Unpacking Tool);
- The relationship between the identified CCC and the SEPs (Unpacking Tool);
- The KSA from which the task is developed (Task Specifications Tool);
- The production of responses that allow students to demonstrate learning of the PE (Task Specifications Tool);
- The attention to required task features (Task Specifications Tool);
- Determination of student evidence to be collected (Classroom-based Assessment Task); and
- Description of the full range of student understanding from low to high levels of competency (Rubric).

Given that there are multiple aspects of the SEPs, DCIs, CCCs, and KSAs, it is the educator's role to select the aspects from the assessment tool's *palette,* which best address the intended learning target of interest from the instructional sequence. Unpacking the dimensions of the PEs and determining the assessment task specifications support an array of distinct, but related, classroom-based assessment

tasks, which allow educators the opportunity to measure students learning against various parts of a three-dimensional PE.

Exhibit 11 is a diagram that illustrates the application of the Unpacking and Assessment Task Specifications Tools in the construction of an assessment task measuring 5-PS1-1: KSA4 – Develop a model to describe that matter is made of particles too small to be seen. Based on the integration of the content and components of the assessment development tools, the diagram indicates in what part of the task they are included.

Exhibit 11. Illustration of Task Features Informed by the Unpacking and Task Specifications Tools

Developing and Using Models
Use a model to describe phenomena.
Reason about the relationship of the different components of a model.
Select and identify relevant aspects of a situation or phenomena to include in the model.

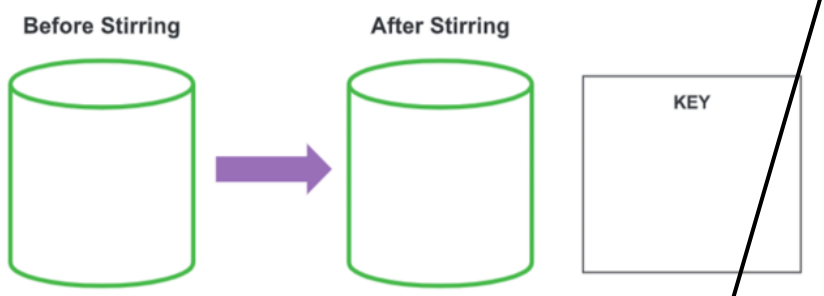
This task is about the particles of matter. Be sure to answer question 1 and question 2.

1. Jose cleaned his salt water fish tank. The water in the tank looked clear. His friend Carl visits and asks, "Why can't I see the salt in the water?" Jose creates a model to show Carl what happens to salt when stirred into water.

Complete the model below to show:

- the salt particles and water particles **before** stirring the mixture
- the salt particles and water particles **after** stirring the mixture

Be sure to complete the key to show the salt particles and water particles in both conditions of your model.



2. Describe the change to the salt particles after being stirred in the water. Be sure to use information from your model to support your explanation.

Student Demonstration of Learning:
Identify and describe relevant relationships between components of a model. Developing and using a model that describes a phenomenon that includes the idea that matter is made of particles too small to be seen.

Task Features:
All tasks must prompt students to describe relationships between observed phenomenon or evidence and reasoning underlying the observation/evidence. All tasks must elicit core ideas as defined in the PE. The items within a task should integrate the dimensions.

Scale, Proportion, and Quantity
Describe relationships between natural objects, which vary in size (very small to the immensely large).

Another way to verify that the example assessment task for 5-PS1-1 specific to KSA4 is aligned to the content and components of the completed assessment tool is shown in Exhibit 12. A record of the task serves as documentation to which the educator can refer to before and after the task is administered. In addition to serving as a "check" on alignment, the educator can use a record of each task to build a "task bank" of developed classroom-based tasks. This repository of tasks can support the generation of new tasks or modification to existing tasks based on an educator's evaluation of accessibility, equity, how well the student responses provide evidence of competency of the measured KSA, and the effectiveness of the rubric criteria to interpret and evaluate student evidence of learning.

Exhibit 12. Verification of Alignment to Aspects of the Unpacking and Task Specifications Tools Integrated into the 5-PS1-1 Classroom-based NGSS Assessment Task

NGSS Performance Expectation: 5-PS1-1

Knowledge, Skills & Abilities: KSA4: Develop a model to describe that matter is made of particles too small to be seen.

Student Demonstration of Learning:

- Developing and using a model that describes a phenomenon that includes the idea that matter is made of particles too small to be seen.
- Identify and describe relevant relationships between components of a model.

Work Product:

- Complete a model
- Constructed-response

Task Features:

- All tasks must prompt students to describe relationships between observed phenomenon or evidence and reasoning underlying the observation/evidence.
- All tasks must elicit core ideas as defined in the PE.
- All tasks must include elements from at least two dimensions of the NGSS.

	Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Foundations	**SEP: Developing and Using Models**	**PS1.A: Structure and Properties of Matter**	**CCC: Scale, Proportion, and Quantity**
Key Aspects	• Use a model to describe phenomena. • Reason about the relationship of the different components of a model. • Select and identify relevant aspects of a situation or phenomena to include in the model.	• Everything around us (matter) is made up of particles that are too small to be seen.	• Describe relationships between natural objects, which vary in size (very small to the immensely large).
Prior Knowledge		• Matter can change in different ways.	**Relationships to SEPs** • Models describe the scale of natural objects.

Conclusion

Assessment is one of three central components—curriculum, instruction, and assessment—of an educational system. Ideally, assessment should measure what students are being taught and are expected to learn (Pellegrino, 2010). With respect to classroom-based science assessment tasks, they should measure a state's three-dimensional science standards. Educators and others responsible for designing and implementing curriculum, instruction, and assessment must understand how students represent knowledge and develop competence in the domain of science. Developing competence in science promotes students' ability to address future challenges and technological advancements in our world and relies upon having high quality assessments of student learning aligned to the NGSS PEs.

The need for a principled-design approach to assessment design, such as ECD, was explicitly discussed in the NRC's report on developing assessments aligned to the NGSS (NRC, 2014). The SCILLSS principled-design approach ensures that classroom-based NGSS science assessment tasks measure the integration of DCIs and CCCs with SEPs that generate meaningful information about students' science learning. The assessment task development tools, based on this principled-design process, are essential in this regard.

Defining the nature of student understanding and developing ways to assess their learning utilizing a principled-design approach is challenging, but achievable. Investing in educators through the provision of time, resources, and collaboration and professional development opportunities can address the challenges of developing classroom-based science assessments that are coherent with curriculum and instruction, produce accurate demonstrations of student learning, and provide flexible opportunities for students to show what they know and can do. The principled-design process and assessment tools in this guide can be capitalized on for such investments in educators and for students who are expected to achieve proficiency overtime with respect to all the PEs in the NGSS.

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Appendices

Appendix A. Grade 5 SCILLSS Classroom-based NGSS Assessment Tools, Tasks, and Rubric for 5-PS1-3

Unpacking the Dimensions Tool for 5-PS1-3

Grade: 5

NGSS Performance Expectation: 5-PS1-3 Make observations and measurements to identify materials based on their properties. [Clarification Statement: 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; density is not intended as an identifiable property.] [*Assessment Boundary: Assessment does not include density or distinguishing mass and weight.*]

	Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Foundations	**SEP: 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.	**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.)	**CCC: Scale, Proportion, and Quantity** Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.
Key Aspects	• Make observations to collect data. • Make measurements to collect data. • Use data from an investigation as evidence for an explanation of a phenomenon or support an explanation. • Identify the purpose of the investigation.	• Properties can be used to identify materials. • Properties can be measured. • Materials can be identified based on their observable and measurable properties. • Properties of materials may include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility.	• Measure and describe physical quantities such as weight, time, temperature, and volume. • Collect and record data according to the given investigation plan.

Prior Knowledge	• Knowledge of units and unit conversions among different-sized standard measurement units within a given measurement system • Knowledge of bar graphs and histograms • Knowledge of line graphs (Note: CCSS Mathematics: "Students solve problems involving information presented in line plots" beginning in grade 5) • Knowledge of how and when to use estimations	• Matter is anything that occupies space and has mass. • Everything around us has unique properties that can be used to identify them, such as what color they are, how hard they are, if they reflect light, whether they conduct electricity or heat, whether they are magnetic, and whether they dissolve in water.	**Relationships to SEPs**	• Models describe the scale of natural objects. • Data analysis serves to interpret quantitative measures of properties, in standard units (e.g., grams, liters). • Planning and carrying out investigations supports students in identifying phenomena to be investigated, and how to observe, measure, and record outcomes.

Assessment Task Specifications Tool for 5-PS1-3

Element	Description
Performance Expectation	**5-PS1-3** Make observations and measurements to identify materials based on their properties.
Knowledge, Skills & Abilities (KSAs)	**KSA1:** Use observations and measurements as evidence to explain the identification of a material. **KSA2:** Use observations of the properties of matter to identify a substance. **KSA3:** Use standard measurements and tools to determine a property of a substance. **KSA4**: Make observations and measurements to identify materials based on their properties.
Student Demonstration of Learning	• Make correct calculations • Use appropriate units • Correct use of quantitative and qualitative data to identify materials based on their properties • Complete and appropriate explanation, using evidence, that materials can be identified based on their observable and measurable properties • Description of why some properties (e.g., shape) are or are not a characteristic property • Use observations to support conclusion, rather than inference
Work Product	• Interpretation of data • Constructed-response • Selected-response
Task Features	• All tasks require evidence of qualitative and quantitative thinking. • All tasks must prompt students to make connections between observed phenomenon or evidence and reasoning underlying the observation/evidence. • Students use scientific reasoning and process skills in observational (nonexperimental) investigations. • All tasks must elicit core ideas as defined in the PE. • All tasks must include elements from at least two dimensions of the NGSS.
Aspects of an assessment task that <u>can be varied</u> to shift complexity or focus	• Properties presented (e.g., color, conductivity, magnetic, conductors) • Format of "real-world" phenomenon under investigation: image, data, text, combination • Standard units used (e.g., grams, liters) • Use or purpose of the model • Type of model (e.g., physical/virtual) • What states of matter are represented and/or included (and how many) and if they are compared
Assessment Boundaries	• Density should not be included as a property. • Mass and weight are not distinguished. • Task may include physical or chemical reactions.

Task Construction: Example 5-PS1-3 Classroom-based NGSS Assessment Task

This task is about the identification of a powder based on its properties. Be sure to answer question 1 and question 2.

The Case of the Mystery Powder

1. A white powder was found on the kitchen floor of a crime scene. A white powder is also found on the shoes of a suspect. To solve the mystery, a detective tests different white powders often found in a kitchen.

   The detective tests how the white powders react when water, heat, and vinegar are added. The test results are shown below in the data table.

Results of Testing White Powders

White Powder	Weight	Water	Heat	Vinegar
Sugar	15g	Dissolves	Melts, bubbles, and smokes	No change
Baking Soda	20g	Turns a milky color	No change	Bubbles
Salt	20g	Dissolves	No change	No change
Plaster of Paris	30g	Turns to a hard solid	No change	Bubbles
Cornstarch	50g	Turns to a soft solid	Turns brown	Thickens

   How could you identify if the powder found on the kitchen floor and the suspect's shoes are the same? Support your explanation by using examples from the data table and what you know about characteristic properties of matter.

2. The characteristics of the white mystery powder found at the scene of the crime match those found on the suspect's shoes. Below are the results of the tests on the two powders.

Results of Testing White Mystery Powder

White Powder	Weight	Water	Heat	Vinegar
Mystery Powder	50g	Turns to a hard solid	No change	Bubbles

   What is the mystery powder? Be sure to support your answer with the information provided in both data tables.

Exemplar 5-PS1-3 High-level Student Responses: Questions 1 and 2

1. "All the powders are white. So, color won't tell what the powder is made of. Each of the powders reacts in a different way when water, heat, or vinegar are tested. If the powder found on the kitchen floor does the same thing as the powder found on the suspect's shoes with water, heat, and vinegar, then it is the same powder."

2. "The powder found in the crime scene and the powder on the suspect's shoes are both plaster of Paris. The color and the weight of the samples don't tell which powder matches. But, the white

mystery powder found at the crime scene has all the same characteristics when heat, water, and vinegar are added like plaster of Paris."

5-PS1-3 Classroom-based NGSS Assessment Task Example Rubric

Dimension Element	1 Students can ...	2 Students can ...	3 Students can ...
Make observations and measurements to produce data to serve as the basis for evidence for an explanation.	Interpret observations from a data table(s) to determine a partial explanation.	Interpret observations from a data table(s) to determine an explanation and link it to the scenario.	Interpret observations from a data table(s), justifying using or not using particular elements of the data to support an explanation linked to the scenario with examples.
Measure and describe physical quantities.	Describe physical properties.	Describe and interpret physical properties in the context of the scenario.	Describe and interpret physical properties in the context of the scenario, noting gaps or limitations in the data.
A variety of properties can be used to identify materials.	Explain the differences in properties of materials, but not necessarily the most relevant or most important aspect of it as it pertains to the scenario.	Explain the differences in properties of materials, in terms that are relevant as it pertains to the scenario.	Explain the differences in properties of materials being focused on and building from the relationships between those elements of the scenario.

Appendix B. Grade 8 SCILLSS Classroom-based NGSS Science Assessment Tools, Tasks, and Rubric for MS-PS4-1

Unpacking the Dimensions Tool for MS-PS4-1

Grade: 8

NGSS Performance Expectation: MS-PS4-1 Use mathematical representations to describe and/or support scientific conclusions and design solutions. A simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [*Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.*]

	Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Foundations	**SEP: Using Mathematics and Computational Thinking** Use mathematical representations to describe and/or support scientific conclusions and design solutions.	**PS4.A: Wave Properties** A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.	**CCC: Patterns** Graphs and charts can be used to identify patterns in data.
Key Aspects	• Use mathematical representations to describe scientific conclusions. • Use mathematical representations to support scientific conclusions. • Use mathematical representations to describe design solutions. • Use mathematical representations to support design solutions.	• A simple wave has a repeating pattern. • A simple wave has a specific wavelength. • A simple wave has a specific frequency. • A simple wave has a specific amplitude. • The wavelength and frequency of a wave are related to one another by the speed of travel of the wave. • The higher the frequency of the wave the shorter the wavelength. • The lower the frequency of the wave the longer the wavelength. • The higher the frequency of the wave the higher the amplitude. • The lower the frequency of the wave the lower the amplitude.	• Use graphs to represent and identify patterns. • Use charts to represent and identify patterns. • Identify the presence of patterns in phenomena or data. • Characterize the strength, direction, or nature of patterns in phenomena or data.

Prior Knowledge	• Knowledge of units and unit conversions • Knowledge of ratio relationships • Ability to interpret qualitative data • Ability to represent proportional relationships • Knowledge of linear relationships	• Waves can cause objects to move. • Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks).	**Relationships to SEPs**	• Explanations address how and why particular patterns occur. • Models describe observed patterns or predict patterns. • Data analysis serves to identify and characterize patterns.

Assessment Task Specifications Tool for MS-PS4-1

Element	Description
Performance Expectation	**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.
Knowledge, Skills & Abilities (KSAs)	**KSA1**: Create a representation that describes a simple wave has a repeating pattern. **KSA2**: Use models and mathematical thinking to demonstrate understanding of wave properties. **KSA3**: Identify patterns as an organizing concept for understanding wave properties. **KSA4**: 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.
Student Demonstration of Learning	• Model accurately represents the observable phenomena • Model accurately captures all mechanistic features of the observable phenomena • Model accurately shows relationships among wave properties • Applies correctly a simple mathematical wave model to a physical system or phenomenon to identify how the wave model characteristics correspond with physical observations • Predicts correctly the change in the energy of the wave if any one of the parameters of the wave is changed • Identifies relevant or meaningful patterns that address a scientific question • Identifies and describes relevant relationships between components of the model • Shows patterns in waves that accurately interpret the relationship between frequency and wavelength
Work Product	• Draw a model • Complete a model • Mathematical representations • Constructed-response
Task Features	• All tasks require evidence of qualitative or quantitative thinking. • All tasks must prompt students to make connections between observed phenomenon or evidence and reasoning underlying the observation/evidence (e.g., related to standard repeating waves). • All tasks must elicit core ideas as defined in the PE. • All tasks must include elements from at least two dimensions of the NGSS.

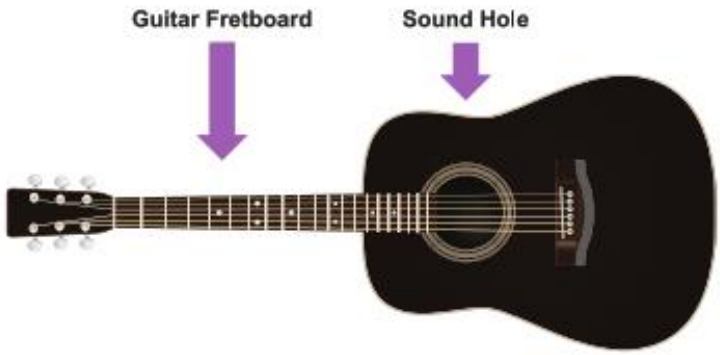
Aspects of an assessment task that <u>can be varied</u> to shift complexity or focus	• Complexity of scientific concept(s) to be represented
	• Function of the representation:
	  ○ to explain a mechanism underlying a phenomenon;
	  ○ to predict future outcomes;
	  ○ to describe a phenomenon;
	  ○ to generate data to inform how the world works
	• The representation may be provided for revision or one that is created from scratch

	• What type of wave is being modeled • Use or purpose of the representation • Type of representation (e.g., mathematical/picture) • Core idea targeted (e.g., sound sources, the medium, deformation, and vibration of an instrument's string)
Assessment Boundaries	• Assessment does not include electromagnetic waves and is limited to standard repeating waves. • Assessment should be limited to qualitative applications pertaining to light and mechanical waves.

Task Construction: Example MS-PS4-1 Science Classroom-based Assessment Task

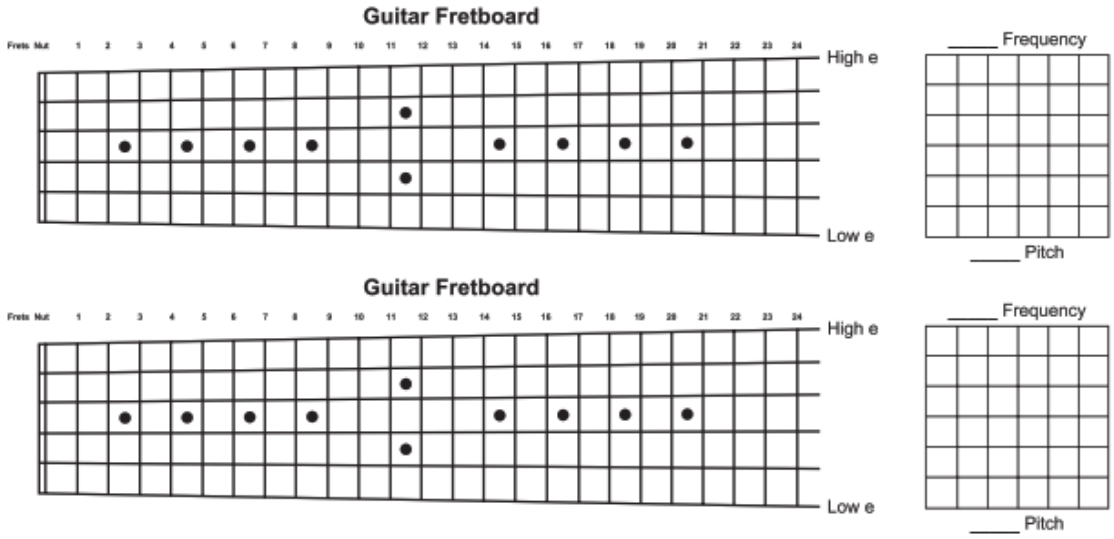
This task is about sound waves.

1. Jenna is learning how to play a guitar. Her guitar is shown below.



Jenna experiments by pressing down her finger on a single string at different locations on the guitar fretboard. When Jenna places her finger on a string near the sound hole, this shortens the length of string that vibrates, called the plucked string. When she places her finger on a string far away from the sound hole, the plucked string has a longer length. Jenna hears different notes.

Two models of Jenna's guitar fretboard are shown below.

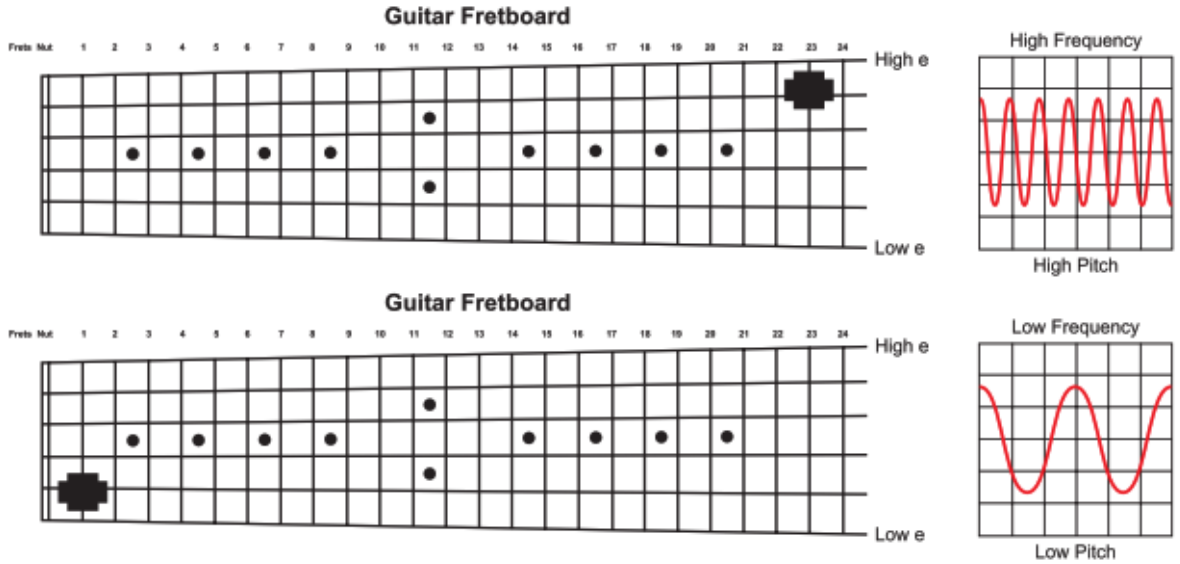


Use the models to show the relationship between the frequency of a sound wave and pitch for a low note and a high note. On each model, be sure to:

- Show the place on the guitar fretboard where a string is held down.
- Label the frequency and pitch of the sound wave that is produced.
- Draw a simple sound wave of that sound on each of the models.

2. What is the relationship between the length of a plucked string and the low or high note produced? Use your model to support your explanation.

Exemplar MS-PS4-1 High-level Student Response: Question 1 Student Model



Exemplar High-level Student Response: Question 2 Student Description

"Stringed instruments have strings that vibrate when plucked or struck. A short string vibrates at a higher frequency and produces a high note with a high pitch. A long string vibrates at a low frequency and produces a lower pitched sound or a low note."

MS-PS4-1 Assessment Task Example Rubric

Student Response	1	2	3
Student creates a model and provides an explanation that describes the relationship between pitch and frequency and uses mathematical thinking to compare rates of vibration (frequency) between strings of different lengths.	Student develops a model that does **not** show the relationship between frequency and pitch and notes played on the guitar. Explanation is incorrect or is not provided.	Student develops a model that shows a slightly flawed connection between frequency, pitch, and the notes played on the guitar (e.g., high frequency paired with low pitch, high note matched low frequency, etc.). Explanation is partially correct (e.g., does not refer to rates of vibration and pitch of the observed sound).	Student creates a model that shows: • relationship between frequency, pitch, and notes played of the guitar • ways that vibrating strings cause differences in sounds Explanation is correct.

Appendix C. Grade 8 SCILLSS Classroom-based NGSS Science Assessment Tools, Tasks, and Rubric for MS-PS4-2

Unpacking the Dimensions Tool for MS-PS4-2

Grade: 8

NGSS Performance Expectation: MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]

	Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Foundations	**SEP: Developing and Using Models** Develop and use a model to describe phenomena.	**PS4.A: Wave Properties** A sound wave needs a medium through which it is transmitted.	**CCC: 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 use.
Key Aspects	• Develop a model to predict phenomena. • Develop a model to describe phenomena. • Identify appropriate aspects of a given phenomenon to include in a model. • Explain the relationships among the components of a model. • Specify or identify the limitations of the model and describe why these limitations exist.	• Sound waves need a medium (air, water, or solid material) to travel through.	• Design structures to serve different functions. • Design structures based on the properties of its materials. • The shape and stability of structures of natural and designed objects are related to their function(s).
Prior Knowledge	• Knowledge of units and unit conversions • Knowledge of ratio relationships • Ability to interpret qualitative data • Ability to represent proportional relationships • Knowledge of linear relationships	• Waves can cause objects to move. • Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks).	**Relationships to SEPs** • A sense of scale is necessary in order to know what properties and what aspects of shape or material are relevant at a particular magnitude or in investigating particular phenomena. • Data analysis serves to demonstrate the relative magnitude of some properties or processes.

Assessment Task Specifications Tool for MS-PS4-2

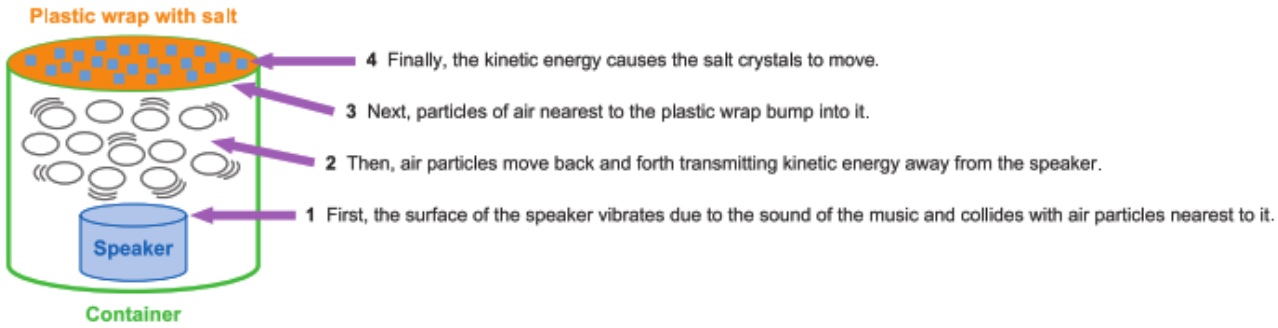
Element	Description
Performance Expectation	**MS-PS4-2** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various material.
The Knowledge, Skills & Abilities (KSAs)	**KSA1**: Develop a model to describe the transmission of waves. **KSA2**: Use a model to make sense of given phenomena involving reflection, absorption, or transmission properties of light and matter waves. **KSA3**: Identify characteristics of the wave after it has interacted with a material (e.g., frequency, amplitude, wavelength). **KSA4**: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various material.
Student Demonstration of Learning	• Model accurately represents the observable phenomena • Model accurately captures all mechanistic features of the observable phenomena • Model accurately shows the transmission of waves • Describes correctly how waves transmit energy • Describes accurately that vibrations in materials set up wavelike disturbances that spread away from the source, such as sound waves • Describes correctly whether the model shows how waves are reflected, absorbed, or transmitted through a material
Work Product	• Draw a model • Complete a model • Constructed-response • Short-response
Task Features	• All tasks require evidence of qualitative and quantitative thinking. • All tasks must prompt students to make connections between observed phenomenon or evidence and reasoning underlying the observation/evidence. • Students use scientific reasoning and process skills in observational (nonexperimental) investigations. • All tasks must elicit core ideas as defined in the PE. • All tasks must include elements from at least two dimensions of the NGSS.
Aspects of an assessment task that <u>can be varied</u> to shift complexity or focus	• Type of wave presented (e.g., sound, electromagnetic, mechanical, light) • Format of "real-world" phenomenon under investigation: image, data, text, combination • Standard units used (e.g., grams, liters) • Use or purpose of the model • Type of model (e.g., physical/virtual) • Core idea targeted in model (e.g., light sources, the materials, polarization of light, ray diagrams)

Assessment Boundaries	• Assessment is limited to qualitative applications pertaining to mechanical waves. • Assessment is limited to standard repeating waves and should not include electromagnetic waves. • Assessment should be limited to qualitative applications pertaining to light and mechanical waves.

Task Construction: Example MS-PS4-2 Science Classroom-embedded Assessment Task

1. Can you make something move by using only sound? Watch the first 20 seconds of the video demonstration here. Develop a model **and** describe this phenomenon using a bowl with plastic cling wrap as the sound detector and a radio speaker as the sound source. Be sure to label the parts of your model. Be sure your model shows:
   - what is happening at the sound source;
   - how the sound source affects the surrounding medium;
   - how the medium causes changes to the sound detector; and
   - what happens to the salt on the sound detector.
2. Based on your model, describe:
   - how sound waves are transmitted through the material;
   - why the salt appears to move differently during the song; and
   - why the plastic wrap acts as a sound detector.

Exemplar MS-PS4-2 High-level Student Response: Question 1 Student Model



Exemplar MS-PS4-2 High-level Student Response to Question 2 Student Description

"The vibrating speaker gives out sound. The sound travels through the air as longitudinal waves. The air particles next to the plastic wrap vibrate as the sound energy reaches it, making the salt crystals move. When the sound of the music is louder, it is more intense. This causes the salt crystals to move even more. The salt stops moving when the sound stops. This is why the plastic wrap is a good sound detector."

MS-PS4-2 Assessment Task Example Rubric

Dimension Element	1 Students can ...	2 Students can ...	3 Students can ...
Develop and use a model to describe phenomena.	Develop a model, which partially describes the phenomenon without indicating relationships between components; did not follow directions to label diagram.	Identify some of the relevant components and/ or describe some of the relationships between components.	Identify relative components and their relationships including: 1) sound waves, 2) materials through which the waves are reflected, absorbed, or transmitted, 3) results of the interaction of the wave and the material, and 4) source of the wave.
Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.	Develop a model with misunderstanding of the properties of the materials.	Interpret the model regarding a part of the context (e.g., no mention of the properties of the material as a sound detector).	Use the model to describe why materials with certain properties are well-suited for particular functions (e.g., a sound detector).
A sound wave needs a medium through which it is transmitted.	Provide a response, which includes major misunderstandings or includes no attempt to show how sound travels or demonstrates little understanding of how sound travels.	Partially describe how sound travels.	Describe how sound waves interact with different materials.

Appendix D. Grade 11 SCILLSS Classroom-based NGSS Science Assessment Tools, Tasks, and Rubric for HS-ESS1-5

Unpacking the Dimensions Tool for HS-ESS1-5

Grade: 11

NGSS 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. [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages 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).]

	Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Foundations	**SEP: 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.	**CCC: Patterns** Empirical evidence is needed to identify patterns.
Key Aspects	• Evaluate the claims behind currently accepted explanations to determine the merits of arguments. • Evaluate the claims behind currently accepted solutions to determine the merits of arguments. • Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. • Evaluate the evidence behind currently accepted solutions to determine the merits of arguments. • Evaluate the reasoning behind currently accepted explanations to determine the merits of arguments. • Evaluate the reasoning behind currently accepted solutions to determine the merits of arguments.	• Active geologic processes have destroyed or altered most of the very early rock record on Earth. • Some objects in the solar system have changed very little over billions of years. • Studying these objects can help deduce the solar system's age and history.	• Identify a pattern in an observed phenomenon. • Explain the pattern in a system under study. • Support a claim about the pattern in a system under study.

Prior Knowledge	• Use linear equations and systems of linear equations to represent, analyze, and solve a variety of problems. • Analyze situations and solve problems. • Knowledge of how to recognize patterns of association in bivariate data • Write an argument.	• Rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history.	**Relationships to SEPs**	• Patterns can be used to support an argument. • Data analysis serves to identify and characterize patterns. • Patterns can be used as empirical evidence for causality in supporting explanations of phenomena.

Assessment Task Specifications Tool for HS-ESS1-5

Element	Description
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.
The Knowledge, Skills & Abilities (KSAs)	**KSA1**: Investigate how Earth's internal and surface processes operate at different spatial and temporal scales to explain the ages of crustal rocks. **KSA2**: Synthesize the relevant evidence to describe the relationship between the motion of continental plates and the patterns in the ages of crustal rocks. **KSA3**: 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.
Student Demonstration of Learning	• Model accurately represents the observable phenomena • Model accurately captures all mechanistic features of the observable phenomena • Use a model to make an accurate prediction about a phenomenon (e.g., direction of plate movement) • Represents only the appropriate relationships and/or interactions among the elements in the model needed to explain the target phenomenon and describes why these relationships are important • Organizes data in a clear way that highlights patterns that are relevant or meaningful to a scientific question • Synthesizes relevant evidence and relevant or meaningful patterns to defend a claim or support an argument
Work Product	• Group discussion • Draw a model • Laboratory exercise • Short-response • Constructed-response
Task Features	• All tasks require evidence of qualitative and quantitative thinking. • All tasks must prompt students to make connections between observed phenomenon or evidence and reasoning underlying the observation/evidence. • Models provided in stimulus materials must illustrate a process or why a phenomenon exists (e.g., plate movement). • All tasks are presented in a context that revolves around movement of crustal rocks. • All phenomena for which a model is developed must be observable or fit available evidence (e.g., plate tectonics to explain the ages of crustal rocks). • Students use scientific reasoning and process skills in observational (nonexperimental) investigations. • All tasks must elicit core ideas as defined in the PE. • All tasks must include elements from at least two dimensions of the NGSS.

Aspects of an assessment task that <u>can be varied</u> to shift complexity or focus	• Complexity of empirical evidence needed to identify patterns • Format of "real-world" phenomenon presented: image, data, text, combination • What characteristics are included (given or determined by the student) • Core idea targeted in model (e.g., the degree to which nuclear processes are included) • The degree to which scientific vocabulary is required/used/scaffolded
Assessment Boundaries	• Students do not need to demonstrate comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems. • Assessment is limited to alpha, beta, and gamma radioactive decays. • Students do not need to calculate radioactive decay rates. • Students do not need to know: names of supercontinents, names of fault lines, names of tectonic plates.

Task Construction Background: Example HS-ESS1-5 Science Classroom-based Assessment Task

This task requires the educator to engage the students in a group discussion after viewing a video related to seafloor spreading found here. The video provides information about the discoveries of Harold Hess related to the process of seafloor spreading that created the oceans' seafloors.

After watching the video, the educator discusses with students how Hess' theory of seafloor spreading relates to the Alfred Wegener (i.e., the originator of the theory of continental drift by hypothesizing in 1912 that the continents are slowly drifting around the Earth). Note: Harry Hess's hypothesis about seafloor spreading had several pieces of evidence to support the theory. One of these is polar reversals. (Students may need clarification about polar reversal. The educator could also have students watch a video that explains this phenomenon found here). Following the group discussion, the students work in small groups to build a model of seafloor spreading. Finally, each student is presented with three questions to which individual responses are provided and evaluated by the educator.

Task Construction: Example HS-ESS1-5 Science Classroom-based Assessment Task

We watched a video about Harry Hess and his theory of seafloor spreading. Let's discuss what we learned and what questions or ideas you might have.

- What important discoveries did Hess and his fellow scientists make?
- Why are models necessary for studying Earth processes?

[After a group discussion about students' answers to the above questions, students will work in small groups to create a model, which incorporates their discussion points including seafloor spreading and the magnetic strips that occur in the seafloor.]

Now you will work with your group to build a model of seafloor spreading using the following materials:

- 1 box lid with a slit cut in the center for the paper strip
- 100 cm long paper strip to be folded in half, with the two ends emerging from the box lid
- 1 box of markers
- 1 bar magnet and 1 compass
- Meter stick

[The performance task requires students to create a group model of seafloor spreading and to pull, mark, flip, etc., using the two poles of the magnet to allow manipulation of the compass to identify the polar reversals (i.e., the magnetic stripes) and using letters (e.g., A, B, C, etc.). Upon completion of the group activity, each student answers the following three questions individually.]

This task is about seafloor spreading. Be sure to answer all three questions.

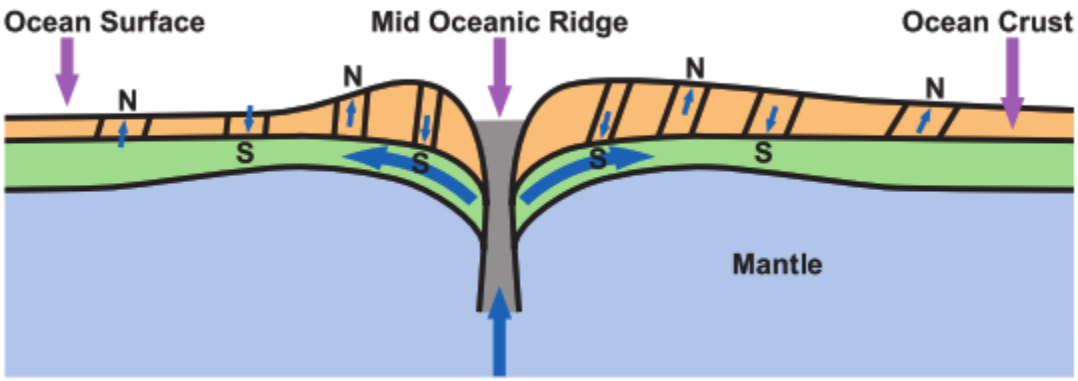
1. What do the following components of the group model represent?
   a. the process of pulling the paper strips
   b. the magnet and what flipping shows
   c. the marked sections of the paper strip (e.g., A, B, C, etc.)
2. In the space below, draw a diagram of seafloor spreading. Include the polar reversals, mid-ocean ridge, oceanic crust, seafloor surface, and direction of movement in the diagram.
3. Use your findings and evidence related to the theories of Hess and Wegner to develop an argument to support the following claim:

   "Crustal materials of different ages are arranged on Earth's surface in a pattern that can be attributed to plate tectonic activity and older rocks are located further away from the mid-ocean ridge."

Exemplar HS-ESS1-5 High-level Student Response: Questions 1 – 3 Student Responses

1. The components represent:
   a. Process of seafloor spreading
   b. The magnet represents Earth's magnetic field and flipping it shows Earth's magnetic reversals.
   c. The different sections are the different orientations of Earth's magnetic field when the seafloor formed.

2.



3. Crustal materials of different ages are arranged on Earth's surface in a pattern that can be attributed to plate tectonic activity. This is supported by data. This includes the magnetic patterns found along these ridges. Based on the north and south magnetic patterns and spacing of magnetic stripes the seafloor grows away from the ridge. So, the motion of the plates moves rocks further and further away from the ridge. This shows that because of that the older rocks are located further away from the mid-ocean ridge and newer rocks are nearer the ridge.

HS-ESS1-5 Assessment Task Example Rubric

Dimension Element	1 Students can ...	2 Students can ...	3 Students can ...
Engaging in Argument from Evidence	Interpret observations from evidence and models to partially support an argument.	Interpret observations from evidence and models and link it to the argument.	Interpret relevant observations from evidence and models, justifying using or not using elements of the data to support an explanation linked to the scenario with examples.
Patterns	Describe physical properties.	Describe and interpret physical properties in the context of the scenario.	Describe and interpret patterns observed from the evidence to support the argument about the ages of crustal rocks.
The History of Planet Earth	Describe seafloor spreading, but not necessarily using the most relevant terms as it pertains to the model.	Explain the motion of continental plates as it pertains to some aspects of the model.	Synthesize the relevant evidence to describe the relationship between the seafloor, magnetic field, mid-ocean ridge, and magnetic reversals shown in the model.

Appendix E. Grade 11 SCILLSS Classroom-based NGSS Science Assessment Tools, Tasks, and Rubric for HS-ESS2-7

Unpacking the Dimensions Tool for HS-ESS2-7

Grade: 11

NGSS Performance Expectation: HS-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [*Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.*]

	Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Foundations	**SEP: Engaging in Argument from Evidence** Construct an oral and written argument or counter-arguments based on data and evidence.	**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.	**CCC: Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.
Key Aspects	• Construct an oral argument based on data and evidence. • Construct a written argument based on data and evidence. • Construct an oral counter-argument based on data and evidence. • Construct a written counter-argument based on data and evidence. • Identify possible weaknesses in either data or an argument and explain why their criticism is justified.	• Feedback (negative or positive) can stabilize or destabilize a system. • The feedbacks between life on Earth and the Earth's systems cause life on Earth to evolve and the surface of the Earth to undergo changes at the same time. • Examples of feedback include how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, thus reducing the amount of sunlight reflected from Earth's surface, which in turn increases surface temperatures and further reduces the amount of ice.	• Construct explanations of how things change. • Construct explanations of how things remain stable. • Evaluate models of complex systems and comprehend subtle issues of stability or of sudden or gradual change over time.

Prior Knowledge	• Use linear equations and systems of linear equations to represent, analyze, and solve a variety of problems. • Analyze situations and solve problems. • Knowledge of how to recognize patterns of association in bivariate data • Write an argument. • Use data to evaluate claims about cause and effect. • Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation	• The evolution and proliferation of living things over geological time have changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere.	**Relationships to SEPs**	• Observations and data describe how things change. • Reasoning and data can be used to explain how things evolved to be the way they are today. • Arguments can be supported by quantifying and modeling changes in systems over very short or very long periods of time. • Explanations of how things evolved to be the way they are today involves modeling rates of change and conditions under which the system is stable or changes gradually, as well as explanations of any sudden change.

Assessment Task Specifications Tool for HS-ESS2-7

Element	Description
Performance Expectation	**HS-ESS2-7** Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth.
The Knowledge, Skills & Abilities (KSAs)	**KSA1**: Construct an argument using causal links and feedback mechanisms between changes in the biosphere and changes in Earth's other systems, that there is simultaneous co-evolution of Earth's systems and life on Earth. **KSA2**: Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth.
Student Demonstration of Learning	• Model accurately represents the observable phenomena • Model accurately captures all mechanistic features of the observable phenomena • Use a model to make an accurate prediction about a phenomenon (e.g., direction of plate movement) • Represents only the appropriate relationships and/or interactions among the elements in the model needed to explain the target phenomenon and describes why these relationships are important • A statement accurately describing how stability and change are related and a good model for a system must be able to offer explanations for both • Organizes data in a clear way that highlights changes observed from the evidence that are relevant or meaningful to a scientific question • Synthesizes relevant evidence related to complex systems and comprehend subtle issues of stability or of sudden or gradual change over time to defend a claim or support an argument or counter-argument
Work Product	• Constructed-response • Short-response • Draw a model
Task Features	• All tasks must prompt students to make connections between observed phenomenon or evidence and reasoning underlying the observation/evidence (e.g., changes in the biosphere and changes in Earth's other systems; ancient versus current atmospheric composition). • All tasks require the use of examples to support a logical argument in a context that revolves around changes in the biosphere and changes in Earth's other systems. • All tasks must elicit core ideas as defined in the PE. • All tasks must include elements from at least two dimensions of the NGSS.
Aspects of an assessment task that <u>can be varied</u> to shift complexity or focus	• Scale of mechanistic relationships in account of how things change and how they remain stable • Complexity of the scientific reasoning required to assess the extent to which the reasoning and data support the argument • Format of "real-world" phenomenon presented: image, data, text, combination
Assessment Boundaries	• Students do not need to demonstrate a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.

Task Construction Background: Example HS-ESS2-7 Science Classroom-based Assessment Task

This task requires the educator to provide a handout with information about the gradual changes in Earth's atmosphere, which support the students in an exploration of a computer-based animation found here.

Task Construction: Example HS-ESS2-7 Science Classroom-based Assessment Task

History of Earth's Oxygen Levels

Early Earth would have been very different and unwelcoming to living things compared to the Earth today. Not only was early Earth covered in lava and constantly erupting, its atmosphere was choked with volcanic gases like carbon dioxide and sulfur dioxide. Volcanic eruptions on land and under the oceans released a lot of iron which, over time, dissolved into seawater. The most important feature of the ancient environment was the absence of oxygen. Therefore, the iron generally stayed dissolved in the seawater.

As Earth cooled, about 4.5 billion years ago, an atmosphere formed mainly from gases spewed from volcanoes. It included hydrogen sulfide, methane, and far greater levels of carbon dioxide than today's atmosphere.

Over millions of years, tectonic movement of the Earth's mantle thrust up the ocean floor to form coastal shallows. A few colonies of bacteria must have found successful survival conditions in these shallows. That's when blue-green algae (cyanobacteria) started the photosynthesis process. The appearance of cyanobacteria is recorded in fossils that formed roughly 3.5 billion years ago. Oxygen began to appear in the oceans. When the dissolved iron interacted with oxygen it precipitated out as iron oxide minerals.

These iron oxide materials, rust, began to form 3.0–2.0 billion years ago. This created black iron oxide minerals (like hematite and magnetite). These minerals, together with iron-poor reddish-colored shales and cherts, collected at the seafloor, and eventually turned into banded iron formations. These are common in rocks 2.8–2.0 billion years old, but do not form today.

In this interactive animation of oxygen levels over time, you will learn about the complex biological and geological factors that have influenced the changes in Earth's oxygen levels. Explore only through 2.4–1.8 billion years ago in the Proterozoic Eon.

1. Thinking like a geologist, use the information from the handout and the evidence presented in the interactive activity to support the following claim.

   "Between 2.5-2.3 billion years ago, levels of oxygen on Earth began to rise."

Exemplar HS-ESS2-7 High-level Student Response: Student Responses

There is biological and geological evidence and facts to support the claim that between 2.5-2.3 billion years ago, the levels of oxygen on Earth rose. For example, there is evidence of cyanobacteria in fossils that are approximately 3.5 billion years old. There was a lot of carbon dioxide in the atmosphere for the cyanobacteria to use for photosynthesis. Photosynthesis releases oxygen. Over millions of years, tectonic movement of the Earth's mantle thrust up the ocean floor to form coastal shallows, thus supporting the spread of more cyanobacteria colonies. This led to greater amounts of oxygen in the environment.

Banded iron formations, a type of sedimentary rock, found in many locations on Earth today, provide evidence for the increase in oxygen released by cyanobacteria. The bands of red and black iron oxides could only have formed in the presence of a lot of oxygen. Also, this phenomenon is found in rocks 2.8-2.0 billion years old. Therefore, it took about a billion years for Earths' oxygen levels to accumulate enough to cause this to occur.

These relationships between iron-rich deposits and Earth's early atmosphere support the claim that between 2.5-2.3 billion years ago, the levels of oxygen rose on Earth.

HS-ESS2-7 Assessment Task Example Rubric

Dimension Element	1 Students can ...	2 Students can ...	3 Students can ...
Engaging in Argument from Evidence	Interpret observations from evidence and models to partially support an argument.	Interpret observations from evidence and models and link it to the argument.	Interpret relevant observations from evidence and models, justifying using or not using elements of the data to support an explanation linked to the scenario with examples.
Stability and Change	Describe physical properties.	Describe and interpret changes biological or geological factors in the context of the scenario.	Describe and interpret changes observed from the evidence to describe the relationship between biological and geological factors that have influenced the changes in oxygen levels during Earth's history.
Biogeology	Compare ancient Earth's atmosphere to today's atmosphere with little understanding of the co-evolution of Earth's systems and life.	Describe the relationship between biological and geological factors to some aspects of the claim that there is continuous co-evolution of Earth's systems and life.	Synthesize the relevant evidence to support the claim that there is continuous co-evolution of Earth's systems and life.