

Table of Contents

New Mexico STEM Ready! Science Standards Implementation Guide	2
Overview	2
The standards	2
Sample Phenomena	4
Classroom Assessment Items	6
Common Misconceptions	8
Multi Layered System of Supports (MLSS)	8
Culturally and Linguistically Responsive Instruction	9
New Mexico Instructional Scope	10
Resources	26

New Mexico STEM Ready! Science Standards Implementation Guide

Overview

A Framework for K-12 Science Education marks a leap forward in how we think about science education and captures the advancements made in understanding how students best learn science that have been made over the last 30 years. The New Mexico Public Education Department and New Mexico public school teachers worked together over the course of June 2021 to construct an Instructional Scope document for the New Mexico STEM Ready! science standards. There are many public schools where high quality instructional materials (HQIM) are present, and these should be used in the teaching of science. In public schools where HQIM may be absent, the New Mexico Instructional Scope for Science (NMIS Science) should be used in conjunction with the New Mexico STEM Ready! science standards to plan science instruction.

The following describes the layout of the NMIS Science document and how it has been designed to be implemented. New Mexico science teachers worked collaboratively to identify and construct sample phenomena, classroom assessment items, common misconceptions, multi-layered systems of supports (MLSS), and culturally and linguistically responsive (CLR) instructional strategies for each performance expectation in the New Mexico STEM Ready! science standards. The best practice of bundling related standards together to capture multiple aspects of a single phenomenon was not done, as local public schools should determine how best to bundle New Mexico STEM Ready! science standards based on their needs.

The standards

What: Each performance expectation begins with links to the *Next Generation Science Standards* and a snapshot of the performance expectation with the relevant Science and Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Cross Cutting Concepts (CCC). Also captured are the connections across the grade level or band (horizontal), connections across grade levels or bands (vertical), and connections to the *Common Core State Standards* (CCSS) in math and English language arts.

The Performance Expectation describes what a student is expected to be able to do at the completion of instruction. They are intended to guide the development of assessments, but they are not the assessment as such. They are not instructional strategies or instructional objectives, but they should influence and guide instruction. Most performance expectations contain a clarification statement and an assessment boundary statement to provide clarity to the performance expectation and guidance to the scope of the expectation, respectively.¹

The foundation box, which is located below the performance expectation, contains the learning goals that students should achieve and that will be assessed using the performance expectations. The three parts to the foundation box are the science and engineering practices, the disciplinary core ideas, and the crosscutting concepts. The information contained in the foundation box is taken directly from *A Framework for K-12 Science Education*. Also included in the foundation box, where appropriate, are connections to engineering, technology, and applications of science as well as connections to the nature of science. These supplemental goals are related to the other material in the foundation box and are intended to guide instructions, but the outcomes are not included in the performance expectation.

The connections box identifies connections to other disciplinary core ideas at this grade level that are relevant to the standard, identifies the articulation of disciplinary core ideas across grade levels, and identifies connections to

¹ Pratt, Harold (2013) *The NSTA Reader's Guide to the Next Generation Science Standards*.

the *Common Core State Standards (CCSS)* in mathematics and in English language arts and literacy that align to this standard. The connections box helps support instruction and development of instructional materials.

Why: The first step of any teacher in planning instruction is to deeply understand the end result that is required. The standards section of the NMIS Science document is placed first so that teachers have quick access to these requirements. The *NGSS* describe the essential learning goals and how those goals will be assessed at each grade level or band.

How: It is generally accepted that planning for instruction begins with the selection of the endpoint, or desired results of the instruction, and working backward through an instructional sequence to the beginning knowledge students have coming into the instruction. The description of such a process has been documented by Wiggins and McTighe in *Understanding by Design* (1998).

For the purpose of the NMIS Science document, a process for moving from the New Mexico STEM Ready! science standards to classroom instruction should minimally include the following²:

- Read the performance expectation, clarification statement, and assessment boundary.
- Read the disciplinary core idea in the foundation box.
 - Read the applicable disciplinary core idea essay in *A Framework for K-12 Science Education*, located in chapters 5, 6, 7, and 8. As you read, consider the following questions:
 - What are some commonly held student ideas about this topic?
 - How could instruction build on helpful ideas and confront troublesome ideas?
 - What prior ideas or concepts do students need to learn to understand this core idea?
 - What level of abstractness is expected of students?
 - What are some phenomena and experiences that could provide observational or experimental evidence that the DCI is an accurate description of the natural world?
 - What representations or media would be helpful for students to use in making sense of the core idea?
- Read the science and engineering practices associated with the performance expectation.
 - Read the applicable SEP essay in *A Framework for K-12 Science Education* located in chapter 3, consider the following questions:
 - While the PE describes one SEP to be used, others will be needed in the instructional sequence, which ones and in what order will you use them?
 - How will each SEP be used to develop an understanding of the DCI?
 - What practices could students engage in to explore phenomena?
- Read the crosscutting concept associated with the performance expectation.

² Bybee, Rodger W. (2013) *Translating the NGSS for Classroom Instruction*.

- Read the applicable CCC essay in *A Framework for K-12 Science Education* located in chapter 4, consider the following questions:
 - How will the CCC indicated in the PE support the understanding of the core idea?
 - Are there other CCC that could also support learning the core idea?
- Read the connections box
 - When reading the connections to other DCI at this grade level that are relevant to the standard, consider the following question:
 - How can instruction be designed so that students note the connections between the core ideas?
 - When reading the articulation of DCI across grade levels that are relevant to the standard, consider the following questions:
 - Examine the standard at earlier grade levels, do they provide an adequate prior knowledge for the core ideas in the standard being reviewed?
 - Examine the standard at later grade levels, does the standard at this level provide adequate prior knowledge for the core ideas in the later standards?
 - When reading the CCSS in mathematics and English language arts (ELA), consider the following questions:
 - Should students have achieved these mathematics and ELA standards to engage in the learning of the science, or could they be learned together?
 - In what ways do the referenced mathematics and ELA standards help clarify the science performance expectations?
 - Can any of the science core ideas be included as examples in the mathematics or ELA instruction?
- Create one or more descriptions of the desired results or learning goals for the instruction integrating the three dimensions in the foundation box.
- Determine the acceptable evidence for the assessment of the desired results.
- Create the learning sequence
 - The NMIS Science document includes sample phenomena, classroom assessment items, common misconceptions, general and targeted supports, and CLR considerations that can be used to assist with this process.
- Create the summative assessment and check its alignment with the performance expectation.

Sample Phenomena

What: Natural phenomena are observable events that occur in the universe and that we can use our science knowledge to explain or predict. The goal of building knowledge in science is to develop general ideas, based on evidence, that can explain and predict phenomena. Engineering involves designing solutions to problems that arise

from phenomena and using explanations of phenomena to design solutions. In this way, phenomena are the context for the work of both the scientist and the engineer.

Why: Despite their centrality in science and engineering, phenomena have traditionally been a missing piece in science education. Anchoring learning in explaining phenomena supports student agency for wanting to build science and engineering knowledge. Students are able to identify an answer to “why do I need to learn this?” before they even know what “this” is. By centering science education on phenomena that students are motivated to explain, the focus of learning shifts from learning about a topic to figuring out why or how something happens. Explaining phenomena and designing solutions to problems allow students to build general science knowledge in the context of their application to understanding phenomena in the real world, leading to deeper and more transferable knowledge. Students who come to see how science ideas can help explain and model phenomena related to compelling real-world situations learn to appreciate the social relevance of science. They get interested in and identify with science as a way of understanding and improving real-world contexts.

Learning to explain phenomena and solve problems is the central reason students engage in the three dimensions of the *NGSS*. Students explain phenomena by developing and applying the DCI and CCC through use of the SEPs. Phenomena-centered classrooms also give students and teachers a context in which to monitor ongoing progress toward understanding all three dimensions. As students are working toward being able to explain phenomena, three-dimensional formative assessment becomes more easily embedded and coherent throughout instruction.

How: We use phenomena to drive instruction to help students engage in practices to develop the knowledge necessary to explain or predict the phenomena. Therefore, the focus is not just on the phenomenon itself. It is the phenomenon plus the student-generated questions about the phenomenon that guides the learning and teaching. The practice of asking questions or identifying problems becomes a critical part of trying to figure something out.

There could potentially be many different lines of inquiry about the same phenomenon. Teachers should help students identify different aspects of the same phenomenon as the focus of their questions. Students also might ask questions about a phenomenon that motivates a line of investigation that isn’t grade appropriate or might not be effective at using or building important disciplinary ideas. Teacher guidance may be needed to help students reformulate questions so they can lead to grade appropriate investigations of important science ideas.

It is important that all students – including English language learners and students from cultural groups underrepresented in STEM – are supported in working with phenomena that are engaging and meaningful to them. Not all students will have the same background or relate to a particular phenomenon in the same way. Educators should consider student perspectives when choosing phenomena and should prepare to support student engagement in different ways. When starting with one phenomenon in your classroom, it is always a good idea to help students identify related phenomena from their lives and their communities to expand the phenomena under consideration.

Not all phenomena need to be used for the same amount of instructional time. Teachers could use an anchoring phenomenon as the overall focus for a unit, along with other investigative phenomena along the way as the focus of an instructional sequence or lesson. They may also highlight everyday phenomena that relate investigative or anchoring phenomena to personally experienced situations. A single phenomenon doesn’t have to cover an entire unit, and different phenomena will take different amounts of time to figure out.

The most powerful phenomena are culturally or personally relevant or consequential to students. Such phenomena highlight how science ideas help us explain aspects of real-world contexts or design solutions to science-related problems that matter to students, their communities, and society. An appropriate phenomenon for instruction should help engage all students in working toward the learning goals of instruction as described by the DCIs, SEPs, and CCCs in the foundation box of the standard.

The process of developing an explanation for a phenomenon should advance students' understanding. If students already need to know the target knowledge before they can inquire about the phenomenon, then the phenomenon is not appropriate for initial instruction. Students should be able to make sense of anchoring or investigative phenomena, but not immediately, and not without investigating it using sequences of the science and engineering practices. Phenomena do not need to be flashy or unexpected. Students might not be intrigued by an everyday phenomenon right away because they believe they already know how or why it happens. With careful teacher facilitation, students can become dissatisfied with what they believe they already know and strive to understand it in the context of the DCI that the teacher is targeting.³

Classroom Assessment Items

What: Classroom assessments (sometimes referred to as internal assessments) is used to refer to assessments designed or selected by teachers and given as an integral part of classroom instruction. This category of assessment may include teacher-student interactions in the classroom, observations of students, student products that result directly from ongoing instructional activities, quizzes tied to instructional activities, formal classroom exams that cover material from one or more instructional units, or assessments created by curriculum developers and embedded in instructional materials for teacher use.⁴

Classroom assessments can be designed to guide instruction (formative purposes) or to support decisions made beyond the classroom (summative purposes). Assessments used for formative purposes occur during the course of a unit of instruction and may involve both formal tests and informal activities conducted as part of a lesson. They may be used to identify students' strengths and weaknesses, assist students in guiding their own learning, and foster students' sense of autonomy and responsibility for their own learning. Assessments for summative purposes may be administered at the end of a unit of instruction. They are designed to provide evidence of achievement that can be used in decision making, such as assigning grades, making promotion or retention decisions, and classifying test takers according to defined performance categories. The results of all these assessments are evaluated by the teacher or sometimes by groups of teachers. These assessments play an integral role in students' learning experiences while also providing evidence of progress in that learning.

Why: In *Developing Assessments for the Next Generation Science Standards*, the National Research Council shared the following conclusions regarding assessing three-dimensional learning:⁵

- Measuring the three-dimensional science learning called for in the framework and the NGSS requires assessment tasks that examine students' performance of scientific and engineering practices in the context of crosscutting concepts and disciplinary core ideas. To adequately cover the three dimensions, assessment tasks will generally need to contain multiple components. It may be useful to focus on individual practices, core ideas, or crosscutting concepts in the various components of an assessment

³ Penuel, W. R., Bell, P., Neill, T., Morrison, D., & Tesoriero, G. (2018). *Selecting Anchoring Phenomena for Equitable 3D Teaching*. [OER Professional Development Session from the ACESSE Project] Retrieved from <http://stemteachingtools.org/pd/sessione>

⁴ National Resource Council. (2014). *Developing Assessments for the Next Generation Science Standards*. Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessments and Board on Science Education, J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors*. Division of Social Sciences and Education. Washington, DC: The National Academies Press.

⁵ National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards*. Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessment and Board on Science Education. J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors*. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

task, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given performance expectation.

- The Next Generation Science Standards require that assessment tasks be designed so they can accurately locate students along a sequence of progressively more complex understandings of a core idea and successively more sophisticated applications of practices and crosscutting concepts.
- The NGSS places significant demands on science learning at every grade level. It will not be feasible to assess all the performance expectations for a given grade level with any one assessment. Students will need multiple – and varied – assessment opportunities to demonstrate their competence on the performance expectations for a given grade level.
- Effective evaluation of three-dimensional science learning requires more than a one-to-one mapping between the NGSS performance expectations and assessment tasks. More than one assessment task may be needed to adequately assess students' mastery of some performance expectations, and any given assessment task may assess aspects of more than one performance expectations. In addition, to assess both understanding of core knowledge and facility with a practice, assessments may need to probe students' use of a given practice in more than one disciplinary context. Assessment tasks that attempt to test practices in strict isolation from one another may not be meaningful as assessments of the three-dimensional science learning called for by the NGSS. (Developing assessments for NGSS, NRC, pp.44-46)

How: The amount of information that has been generated around designing and creating three-dimensional assessment tasks to meet the conclusions laid out above by the National Research Council has been overwhelming. The following free resources are available through STEM teaching tools to help you navigate this flood of information and translate it into your classroom. You should start by familiarizing yourself with the following STEM Teaching Tools⁶:

- Practice Brief 18 on how teachers can develop formative assessments that fit a three-dimensional view of science learning.
- Practice Brief 26 on how to design formative assessments that engage students in three-dimensional learning.
- Practice Brief 30 on integrating science practices into assessment tasks
- Practice Brief 41 on integrating cross cutting concepts into assessment and instruction
- Practice Brief 33 on designing assessments for emerging bilingual students

In general, one can use the following process to develop classroom assessment tasks:

1. Identify specific learning goals for the desired assessment
2. Brainstorm assessment scenarios that involve phenomena that clearly foreground the identified learning goals
3. Prioritize and select a scenario that best fits the following criteria:
 - a. it should allow students from non-dominant communities (e.g., ELLs, students from poverty-impacted communities) to fully engage with the task,

⁶ STEM Teaching Tools (n.d.), <http://stemteachingtools.org/tools> accessed on July 7, 2021

- b. it should involve a compelling phenomenon related to one or more of the DCIs being assessed—and not feel like a test-like task,
 - c. it should be quickly understandable by students, and
 - d. it should lend itself to a broad range of science and engineering practices.
4. The task formats (practice briefs 30 and 41) provide detailed guidance on how to design assessment components that engage students in the science and engineering practices. Identify the practices that relate to the scenario and use the task formats to craft assessment components
5. Write hypothetical student responses for each prompt: some that reflect limited, partial, and full levels of understanding
6. Share tasks with colleagues and ask for feedback about the alignment of goals, scenarios, and hypothetical student responses

Common Misconceptions

What: This planning support identifies some of the common misconceptions students develop about a scientific topic.

Why: Our brains are highly advanced cause and effect reasoning machines. From birth, we begin to analyze effects to determine causes and provide some sort of reasoning for the whole event. The more events that support our reasoning, the stronger that learning becomes. So, every student in your classroom brings their own unique background knowledge into your classroom. Some of this is aligned to scientific understanding and some of this is misaligned to scientific understanding but aligned to that student’s personal experiences. As science educators, we must always create space for students to bring their current understanding about a topic into our classroom so that we can begin to address understandings that are misaligned to scientific understanding. Some of these misunderstandings are not unique to a single student; rather, they are common to many students.

How: When planning with your HQIM look for ways to directly address with students some common misconceptions. The planning supports in this document provide some possible misconceptions and your HQIM might include additional ones. The goal is not to avoid misconceptions, they are a natural part of the learning process, but we want to support students in exploring the misconception and modifying incorrect or partial understandings.

Multi Layered System of Supports (MLSS)

What: The Multi-Layered Systems of Support (MLSS) is designed to support teachers in planning instruction for the needs of all students. Each section identifies general supports (layer 1) for supporting pedagogically sound whole class science instruction and targeted supports (layer 2) for supporting those scholars that teachers identify as not understanding the topic. We recognize there is a need for intensive support (layer 3) for those students needing longer duration or otherwise more intense support with a given topic; however, this was not part of the NM IS Science 1.0 work.

Why: MLSS is a holistic framework that guides educators, those closest to the student, to intervene quickly when students need additional support. The framework moves away from the “wait to fail” model and empowers teachers to use their professional judgement to make data-informed decisions regarding the students in their classroom to ensure academic success with grade level expectations of the New Mexico Science Standards.

How: When planning with your high-quality instructional materials (HQIM) use the suggested universal supports embedded in the sequence of instruction. If you do not have access to HQIM in your school, the universal (layer 1) support in this document can be used in planning your instruction.

Culturally and Linguistically Responsive Instruction

What: Culturally and Linguistically Responsive Instruction (CLRI), or the practice of situational appropriateness, requires educators to contribute to a positive school climate by validating and affirming students' home languages and cultures. Validation is making the home culture and language legitimate, while affirmation is affirming or making clear that the home culture and language are positive assets. It is also the intentional effort to reverse negative stereotypes of non-dominant cultures and languages and must be intentional and purposeful, consistent and authentic, and proactive and reactive. Building and bridging is the extension of validation and affirmation. By building and bridging students learning to toggle between home culture and linguistic behaviors and expectations and the school culture and linguistic behaviors and expectations. The building component focuses on creating connections between the home culture and language and the expectations of school culture and language for success in school. The bridging component focuses on creating opportunities to practice situational appropriateness or utilizing appropriate cultural and linguistic behaviors.

Why: Student understanding of science is shaped by their interactions with phenomena throughout their lives. Science educators must intentionally and purposefully legitimize the home culture and languages of students and validate their ways of knowing and understanding. In addition, create connections between the cultural and linguistic behaviors of the students' home culture and language and the culture and language of scientific understanding.

How: When planning instruction it is critical to consider ways to validate/affirm and build/bridge from your students' cultural and linguistic assets. There has been an overwhelming amount of guidance within STEM education about CLRI. The following STEM teaching tools can be a good place to start wrapping your mind around this topic.⁷

- Practice Brief 15: Promoting equity in science education
- Practice Brief 47: Promoting equitable sensemaking
- Practice Brief 54: Building equitable learning communities
- Practice Brief 11: Indigenous ways of knowing and STEM
- Practice Brief 27: Engaging English language learners in science and engineering practices
- Practice Brief 71: Advancing equity and justice in science education
- Practice Brief 53: Avoiding pitfalls associated with CLRI

The planning supports for each performance expectation provide an example of how to support equity-based teaching practices. Look for additional ways within your HQIM to ensure all students are included in the pursuit of scientific understanding in your classroom.

⁷ STEM Teaching Tools (n.d.), <http://stemteachingtools.org/tools> accessed on July 7, 2021

STANDARDS BREAKDOWN

Physical Science: Waves and their Applications in Technologies for Information Transfer

[PS4-1](#)

[PS4-2](#)

[PS4-3](#)

Students who demonstrate understanding can:

- 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. [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.]

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

Science and Engineering Practices

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

Crosscutting Concepts

Patterns

- Graphs and charts can be used to identify patterns in data.

Connections to other DCIs in this grade-band: N/A

Articulation of DCIs across grade-bands:

4.PS3.A ; 4.PS3.B ; 4.PS4.A ; HS.PS4.A ; HS.PS4.B

Common Core State Standards Connections:

ELA/Literacy -

SL.8.5

Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1)

Mathematics -

MP.2

Reason abstractly and quantitatively. (MS-PS4-1)

MP.4

Model with mathematics. (MS-PS4-1)

6.RP.A.1

Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1)

6.RP.A.3

Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS4-1)

7.RP.A.2

Recognize and represent proportional relationships between quantities. (MS-PS4-1)

8.F.A.3

Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (MS-PS4-1)

Grade	NGSS Discipline
MS	<u>Physical Science 4.1</u>
PS4-1	Sample Phenomena

When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.

OpenSciEd 8.2: Sound Waves - How can sound make something move? How does a sound source make something like this happen? <https://www.openscienced.org/8-2-sound-waves-download/>

Loud music from a truck makes a window in the parking lot move. A speaker moved when it produced sound. We observe a perplexing phenomenon: Sound from a truck appears to make a window move from the parking lot. We note observations of this phenomenon as well as of a speaker in the classroom. Our observations, models, and other sound-related phenomena lead us to add a broad set of questions about sound to our DQB and to list ideas for investigations to pursue.

Amazing Slinky Tricks

Description: The Slinky was invented by Richard James, an engineer, who was working with springs to support and stabilize equipment on a ship. Simple slinky tricks show how forces (pushes and pulls) change the direction of an object. Students can design a set of stairs, or obstacles, that the Slinky can navigate. In the secondary science classroom it can be used to investigate inertia, oscillations, and Hooke's law. This phenomenon can also be used to investigate wave properties.



Video Example: [Amazing Slinky Tricks — The Wonder of Science](#)

Rubens' Tube

Description: The Rubens' tube was invented by German physicist Heinrich Rubens in 1905. It is a tube that is sealed at both ends and includes a flammable gas like propane. A speaker is attached to one end of the tube so sound waves can be transmitted through the air/gas mixture. Small holes are drilled in the top of the tube and when the air/gas mixture emerges it creates a flame. As sound is played standing waves are created in the flames that change as the frequency of the waves is changed.



Video Example: [Rubens' Tube — The Wonder of Science](#)

Self-Leveling Pool Table On Cruise Ship

Description: This pool table on the cruise ship Radiance of the Seas uses gyroscopic leveling to keep the pool table level during rough seas. This design solution could be used to start a unit on waves. After learning more about the amplitude, wavelength and energy of waves students could attempt to build a similar solution of their own.



Video Example: [Self-Leveling Pool Table On Cruise Ship — The Wonder of Science](#)

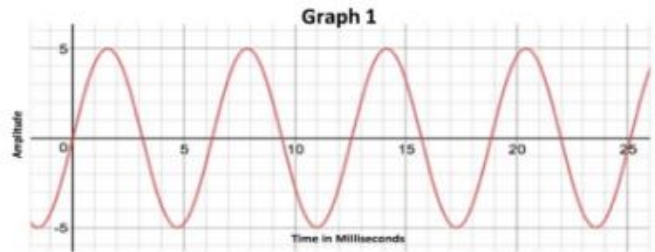
Classroom Assessment Items

When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

[MS-PS4-1 Assessment - Sounds in Space](#) from Wonder of Science from [Stanford NGSS Assessment Project \(SNAP\)](#)

You are on a team that is developing a game about people in outer space. You are using a computer program to create the sounds that will be used in the game. To make the sounds on your computer you have to change the characteristics of sound waves.

Graph 1 shows a sound (one note) you are working on.

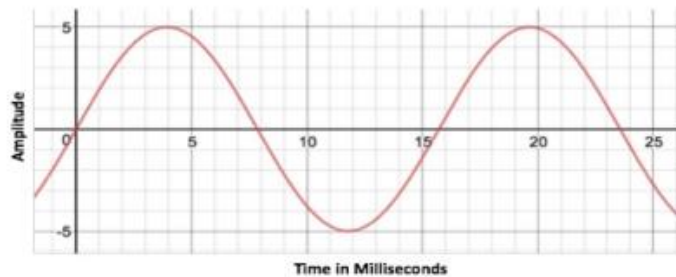


1. One way you can change the sound is to increase or decrease its frequency. Which of the graphs below shows how **Graph 1** would change if you increased **only the frequency** of the wave? **Graph** _____.

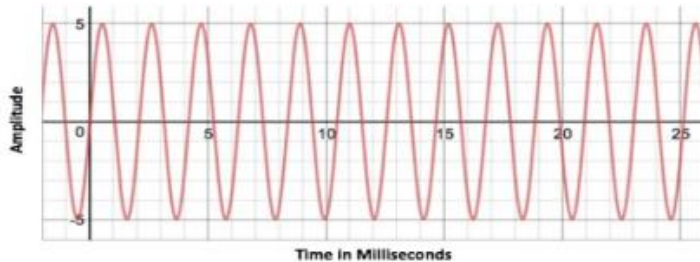
Graph A



Graph B

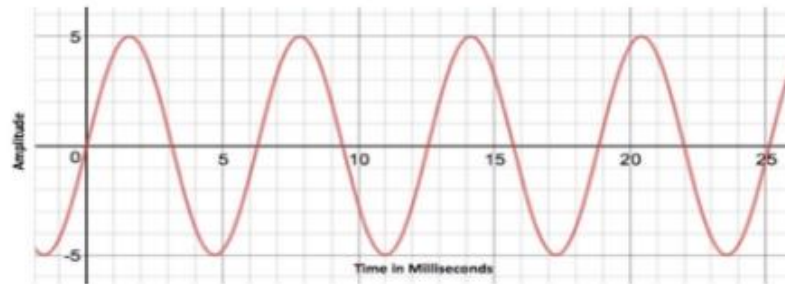


Graph C

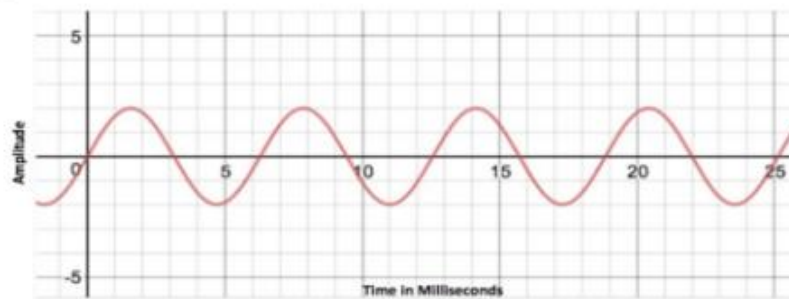


The following graphs (Graph 1 and Graph 2) show two different graphs for the same note.

Graph 1



Graph 2



2. When the computer program plays the sound wave shown in Graph 1, how do you think it will be different from sound made with Graph 2? Use evidence from the graphs and what you know about waves (wavelength, frequency, and amplitude) to support your claim.

Universal Supports

- Layer 1** - Students should be able to identify the characteristics of a simple mathematical wave model including the knowledge that waves represent repeating quantities, frequency, amplitude, and wavelength. Students should apply the simple mathematical wave model to a physical system or phenomenon to identify how the wave model characteristics correspond with physical observations (e.g., frequency corresponds to sound pitch, amplitude corresponds to sound volume). Students should be able to use their simple mathematical wave models to identify patterns about a repeating physical phenomenon that can be represented as a wave, and amounts of energy present or transmitted including
 - That the energy of the wave is proportional to the square of the amplitude (e.g., if the

Targeted Supports

- Layer 2** - Support can include vocabulary assistance, different waveforms for students to determine the frequency, amplitude, and wavelength and use this information to predict the change in energy if one of these variables is changed.

- height of a water wave is doubled, each wave will have four times the energy).
2. That the amount of energy transferred by waves in a given time is proportional to frequency (e.g., if twice as many water waves hit the shore each minute, then twice as much energy will be transferred to the shore).

Common Misconceptions

- When a wave moves through a medium, particles of the medium move along with the wave.
- Gamma rays, x-rays, ultraviolet light, visible light, infrared light, microwaves and radio waves are different entities.
- When two pulses, traveling in opposite directions along a spring or rope meet, they bounce off each other and go back in the opposite direction.
- Period, frequency and wavelength are interchangeable
- Amplitude affects wavelength and/or frequency

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

Ask students: What knowledge and experiences have you had with waves?

Build and Bridge:

Ask students: Why would it be important for you or your community to understand the mathematical relationships that exist in waves?

Build a driving question Bulletin where students can stick questions and re- address their learning through time. Revisit this board often to help students make sense of their science learning. Bring those questions to group discussion.

Students who demonstrate understanding can:

- 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.]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

PS4.A: Wave Properties

- A sound wave needs a medium through which it is transmitted.

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Crosscutting Concepts

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Connections to other DCIs in this grade-band:

MS.LS1.D

Articulation of DCIs across grade-bands:

4.PS4.B ; HS.PS4.A ; HS.PS4.B ; HS.ESS1.A ; HS.ESS2.A ; HS.ESS2.C ; HS.ESS2.D

Common Core State Standards Connections:

ELA/Literacy -

SL.8.5

Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (*MS-PS4-2*)

Grade	NGSS Discipline
MS	<u>Physical Science 4.2</u>
PS4-2	<p data-bbox="282 1556 1523 1633">Sample Phenomena</p> <p data-bbox="282 1654 1523 1745"><i>When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.</i></p> <p data-bbox="282 1772 1523 1808">Rubens' Tube</p>

Description: The Rubens' tube was invented by German physicist Heinrich Rubens in 1905. It is a tube that is sealed at both ends and includes a flammable gas like propane. A speaker is attached to one end of the tube so sound waves can be transmitted through the air/gas mixture. Small holes are drilled in the top of the tube and when the air/gas mixture emerges it creates a flame. As sound is played standing waves are created in the flames that change as the frequency of the waves is changed.

[Daniel Kish Uses Echolocation To Navigate](#)

Description: Daniel Kish lost his eyes to cancer before he was 13 months old. He uses echolocation by listening to the reflection of sound waves to navigate in 3D space. He can even ride a bicycle. In addition to being an incredible story of perseverance this is a perfect phenomenon for a unit on waves. Sound waves are reflected, absorbed, and transmitted through objects in the environment and Daniel can sense the changes in energy of the returning waves.

[The Shadow Illusion](#)

Description: Derek Muller from Veritasium uses the shadow illusion to show that the size and shape of a pinhole does not affect the image projected. Most of the participants believe they are looking at the shape of the hole rather than the shape of the Sun projected on the wall. This could be an excellent phenomenon to start a unit on light or vision.

Classroom Assessment Items

When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

[**It's not magic, it's science!**](#)

Background

As light travels through a given substance, it travels in a straight line. For example, sunlight travels through air along a straight path. However, when light passes from one substance into a different substance, the speed of light changes and the path bends. For example, when sunlight moves from air to water, the path of light bends. This phenomenon is called "refraction." The refraction only occurs at the boundary between the two substances; for example, the boundary between air and water. Once the light has crossed the boundary, it continues to travel in a straight line at a constant speed.

Different substances cause light to bend different amounts. The amount that a certain material bends light is called its "refraction index." A substance with a big refraction index causes light to slow down a lot and...

The index of refraction values provide a measure of the relative speed of a light wave in a particular medium. Knowledge of such relative speeds allows a student of physics to predict which way a light ray would bend when passing from one medium to another. The higher the refractive index, the slower the light will move. The lower the refractive index, the faster light will move.

A material that has a high index of refraction, like a diamond, will bend light more than a material with lower index of refraction, like water.

Substance	Refractive index
Water	1.330
Vegetable oil	1.47
Isopropyl alcohol	1.377
Air	1.000

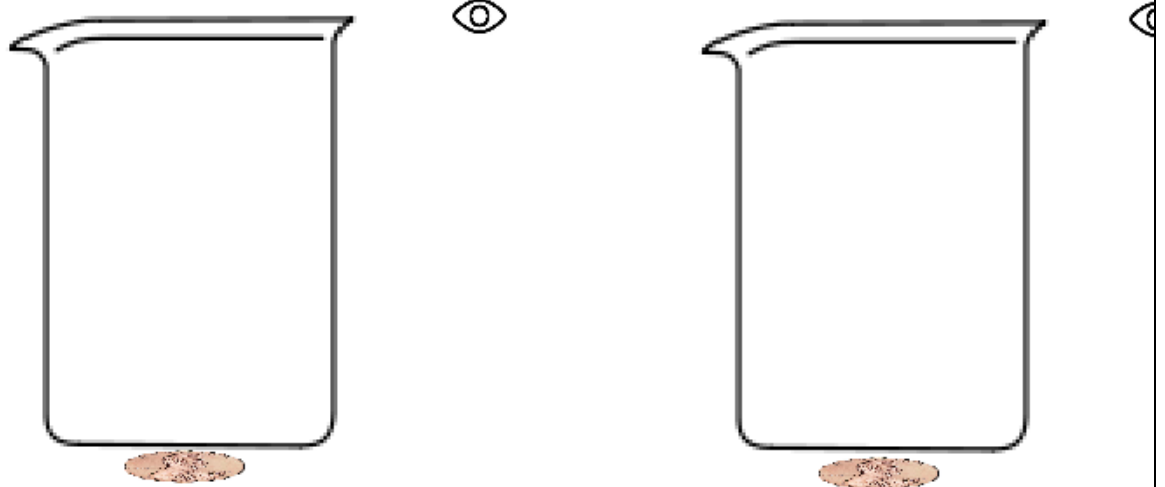
Sources:

<https://www.sciencelearn.org.nz/resources/49-refraction-of-light>

<http://www.raeco.com/training/refractive-index-values.htm>

<https://www.optics4kids.org/classroom-activities/10-15/lose-a-glass-in-a-glass>

- 1) How does the type of the material affect the speed of light (structure and function)?
- 2) Create a model of the phenomena that shows the science behind the magic of the disappearing penny.



It's not magic, it's Science!

Directions: At the State Fair in Syracuse, a famous magician, The Mysterious Luna, shows the attendees a magic trick involving a special coin, water and light. Luna places a magical coin from the Far East in the bottom of a magical glass. Three people are chosen randomly from the audience to watch what happens when she pours water into the vessel. Amazingly, the coin disappears and the crowd applauds!

Observe this phenomena in your class, compared to an empty beaker of water.

Part 1: Phenomena

Part 2: Additional Information (The Stimulus)

Part 3: Task (The Prompt)

- 1) How does the type of the material affect the speed of light (structure and function)?

Universal Supports

- **Layer 1:** Given materials from a variety of different types of sources of information (e.g., texts, graphical, video, digital), students gather evidence sufficient to support a claim about a phenomenon that includes the idea that using waves reflected, absorbed and transmitted via different materials. Students combine the relevant information (from multiple sources) to support the claim by describing:
 1. What are the different types of waves?
 2. Light travels in straight lines, but the path of light is bent at the interface between materials when it travels from one material to another.
 3. differences between how light and mechanical waves interact with different materials.

Targeted Supports

- **Layer 2 -** Support for the misconceptions and interpretation. The brightness of light is dependent on the color (frequency) as well as amplitude.

Common Misconceptions

- The brightness of light is dependent on the color (frequency) as well as amplitude.
- A sound wave is the movement of air particles.
- A physical wave is a movement of matter.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm :

Ask students: What knowledge and experiences have you might help us as a class explain -Matter waves created by a tuning fork vocal chords

Build and Bridge:

Ask students: Why would it be important for you or your community to understand how waves travel in different materials

Build a driving question Bulletin where students can stick questions and re- address their learning through time. Revisit this board often to help students make sense of their science learning. Bring those questions to group discussion.

Students who demonstrate understanding can:

- MS-PS4-3.** Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 6-8 builds on K-5 and progresses to evaluating the merit and validity of ideas and methods.</p> <ul style="list-style-type: none"> Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. 	<p>PS4.C: Information Technologies and Instrumentation</p> <ul style="list-style-type: none"> Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. 	<p>Structure and Function</p> <ul style="list-style-type: none"> Structures can be designed to serve particular functions. <p>-----</p> <p><i>Connections to Engineering, Technology, and Applications of Science</i></p> <p>-----</p> <p>Influence of Science, Engineering, and Technology on Society and the Natural World</p> <ul style="list-style-type: none"> Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. <p>-----</p> <p><i>Connections to Nature of Science</i></p> <p>-----</p> <p>Science is a Human Endeavor</p> <ul style="list-style-type: none"> Advances in technology influence the progress of science and science has influenced advances in technology.
<p><i>Connections to other DCIs in this grade-band: N/A</i></p> <p><i>Articulation of DCIs across grade-bands:</i> 4.PS4.C ; HS.PS4.A ; HS.PS4.C</p> <p><i>Common Core State Standards Connections:</i> ELA/Literacy - RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3) RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3) RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3) WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3)</p>		

Grade	NGSS Discipline
MS	<u>Physical Science 4.3</u>
PS4-3	Sample Phenomena
	<p><i>When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.</i></p> <p>From: Understanding White Sharks</p> <p>Investigative Phenomena: The REMUS “shark cam” provides a more reliable method of getting information on white sharks at the expense of potentially interrupting/influencing white shark behavior.</p>

Description: Sharks are adapted for sensing in the water (for example, they can detect electric fields. Sound waves enable tracking devices to gather information on white sharks. Tracking devices encode and transmit information. Digitized Signals are more reliable in transmitting information than analog signals.

Video Example: [REMUS SharkCam: The Hunter and the Hunted](#)

Analog vs. Digital Television

Description: In this video an analog and a digital television signal are compared. Many students today are not familiar with analog television and the problem of static. Analog television uses changes in the amplitude, frequency or phase of the radio waves to transmit information. Problems of this technology include susceptibility to interference (or static), color consistency, and a smaller image. Digital sends the information as a series of 0's and 1's that are converted into the pixels on the screen. It is difficult to find analog television signals in the US but the radio is a great substitute.



Video Example: [Analog vs. Digital Television — The Wonder of Science](#)

Photoelectric Effect

Description: The photoelectric effect is the emission of electrons when a material is hit with light exceeding a threshold frequency. This provides evidence that light can act as a particle, as well as a wave. Practical applications of this phenomenon include solar cells and image sensors in digital cameras. This demonstration of the photoelectric effect only requires an electroscope, a metal plate and an ultraviolet light.



Video Example: [Photoelectric Effect — The Wonder of Science](#)

Classroom Assessment Items

When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

[MS-PS4-3 Assessment - Preserving Grandma's Family Memorabilia](#) from Wonder of Science

You visit your grandmother who has boxes of photo albums, important family documents, and home videos (on VHS). There are a lot of family memories in this media but everything is starting to fade and fall apart and you want to preserve it and make it accessible for the next generation. In addition, you want to be able to reliably and quickly send this memorabilia to your family members who live all over the world.

Stimulus

Table 1: Analog vs. Digital Waves Structure and Function

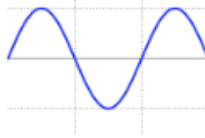

	Analog	Digital
Signal	Analog signals are continuous signals	Digital signals are discrete (binary) signals
Waves	Denoted by sine (curvy) waves 	Denoted by square (block) waves 
Examples	Human voice in air, record player, cassette tape, VHS tapes	Computers, CDs, DVDs, mP3s, digital photos, and cell phones
Uses	Can be used in analog devices only	Used in computing and digital electronics

Table 2: Advantages and Disadvantages of Analog vs. Digital Waves

Signal	Advantages	Disadvantages
Analog	Tape recordings have been proven to be useful Records and record albums have artistic value	Tape players or record players are difficult to find A tape (audio and video) can break Copying a tape can deteriorate the quality

Digital	<p>More data in a smaller space</p> <p>No degradation of data</p> <p>Data can be shared electronically</p> <p>Data can be stored remotely (in "the cloud")</p>	<p>Computers crash</p> <p>Software needs to be up to date</p> <p>Digital data can be corrupted or hacked</p> <p>Digital technology can change and making access difficult (i.e. laserdisc player)</p>
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Watch this video comparing digital and analog media <https://www.youtube.com/embed/btgAUdbj85E>

Prompt
<p>Use evidence that you gather from the tables and video clip to explain to your grandmother why she should digitize her media collection of family memories.</p> <p>a) What benefits would grandma, and the family, gain from digitizing her media collection?</p> <p>b) What specific features of the digital media allow it to be more reliably transmitted globally than the analog media?</p>
<p>Claim</p> <p>Digitizing family media; including photos, home movies, and important documents, would be a better way to preserve, store, and share family history.</p>
<p>Reasoning (What is your explanation?)</p>
<p>Evidence: list 3 pieces of evidence that you have collected to support your explanation (Why?)</p>

Universal Supports	Targeted Supports
<ul style="list-style-type: none"> Layer 1 - Given materials from a variety of different types of sources of information (e.g., texts, graphical, video, digital), students gather evidence sufficient to support a claim about a phenomenon that includes the idea that using waves to carry digital signals is a 	<ul style="list-style-type: none"> Layer 2 - Support for the misconceptions and interpretation of why not all waves are the same when it comes to their applications in science.

more reliable way to encode and transmit information than using waves to carry analog signals. Students combine the relevant information (from multiple sources) to support the claim by describing:

1. Specific features that make digital transmission of signals more reliable than analog transmission of signals, including that, when in digitized form, information can be recorded reliably, stored for future recovery, and transmitted over long distances without significant degradation.
2. At least one technology that uses digital encoding and transmission of information. Students should describe how the digitization of that technology has advanced science and scientific investigations (e.g., digital probes, including thermometers and pH probes; audio recordings).

Common Misconceptions

- The terms analog and continuous are synonymous.
- Digital is always better.
- Digital audio recordings cannot match the quality of analog recordings.
- Radio waves continue on into space forever
- More Wi-Fi hotspots are better
- Radio Frequency signals carrying digital data go further than radio frequency signals with analog data
- Encryption makes the radio frequency signal invisible and prevents it from being intercepted

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm :

Ask students: When you hear data, what do you think of? What are the different ways you and your family store data? What types of data are most important to your community?

Build and Bridge:

Ask students: Why would it be important for you or your community to understand the differences between analog and digital technologies?

Build a driving question Bulletin where students can stick questions and re- address their learning through time. Revisit this board often to help students make sense of their science learning. Bring those questions to group discussion.

Section 3: Resources

Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge.⁸ Our core science instruction must also allow for students to develop their science and engineering practices over time in addition to disciplinary core ideas. We know that children enter kindergarten with a surprisingly complex way of thinking about the world.⁹ We know that students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas' interconnections over a period of years rather than weeks or months.² We know that in order for students to develop a sustained attraction to science and for them to appreciate the many ways in which it is pertinent to their daily lives, classroom learning experiences in science need to connect with their own interests and experiences.¹ To this end, the National Research Council lays out a three-dimensional framework that is foundational to the development of the *Next Generation Science Standards (NGSS)*.

Dimension 1 describes the scientific and engineering practices (SEP). Dimension 2 describes the crosscutting concepts (CCC). Dimension 3 describes the core ideas (DCI) in the science disciplines and the relationships among science, engineering, and technology. All three of these dimensions must be interwoven in curriculum, instruction, and assessment.¹

Engaging in the Practices of Science

Students provided sustained opportunities to engage in the practices of science and engineering better understand how knowledge develops and provides them an appreciation of the diverse strategies used to investigate, model, and explain the world.¹ The practices for K-12 science classrooms are:

1. Asking questions (science) and defining problems (engineering)
 - a. Science asks:
 - i. What exists and what happens?
 - ii. Why does it happen?
 - iii. How does one know?
 - b. Engineering asks:
 - i. What can be done to address a particular human need or want?
 - ii. How can the need be better specified?
 - iii. What tools or technologies are available, or could be developed, for addressing this need?
 - c. Both ask:
 - i. How does one communicate about phenomena, evidence, explanations, and design solutions?
2. Developing and using models
 - a. Mental models: functional, used for thinking, making predictions, and making sense of experiences.
 - b. Conceptual models: allow scientists and engineers to better visualize and understand phenomena and problems.

⁸ National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

⁹ National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. Committee on Science Learning, Kindergarten through Eighth Grade. R.A. Duschl, H.A. Schweingruber, and A.W. Shouse (Eds.). Board of Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

- c. Are used to represent current understanding of a system (or parts of a system) under study, to aid in the development of questions or explanations, and to communicate ideas to others.
3. Planning and carrying out investigations
 - a. Used to systematically describe the world and to develop and test theories and explanations of how the world works.
4. Analyzing and interpreting data
 - a. Once collected, data are presented in a form that can reveal any patterns and relationships and that allows results to be communicated to others.
5. Using mathematics and computational thinking
 - a. Enables the numerical representation of variables, the symbolic representation of relationships between physical entities, and the prediction of outcomes.
6. Constructing explanations (science) and designing solutions (engineering)
 - a. Explanations are accounts that link scientific theory with specific observations or phenomena.
 - b. Engineering solutions must include specifying constraints, developing a design plan, producing and testing models/prototypes, selecting among alternative design features to optimize achievement, and refining design ideas based on prototype performance.
7. Engaging in argument from evidence
 - a. Scientists and engineers use reasoning and argumentation to make their case concerning new theories, proposed explanations, novel solutions, and/or fresh interpretations of old data.
8. Obtaining, evaluating, and communicating information
 - a. Being literate in science and engineering requires the ability to read and understand their literature. Science and engineering are ways of knowing that are represented and communicated by words, diagrams, charts, graphs, images, symbols, and mathematics.

STEM teaching tools develop briefs to assist STEM teachers with issues that arise in the teaching of STEM. Here are some briefs that address scientific practices. All of these can be found at www.stemteachingtools.org/tools

Why focus on science and engineering practices – and not “inquiry?” Why is “the scientific method” mistaken? - STEM teaching tool #32

For decades science education has engaged students in a version of science inquiry that reduces the investigation of the natural world to a fixed, linear set of steps—sometimes devoid of a deep focus on learning and applying science concepts. Rigid representations of a single “scientific method” do not accurately reflect the complex thinking or work of scientists. The new vision calls for engaging students in multifaceted science and engineering practices in more complex, relevant, and authentic ways as they conduct investigations.

Practices should not stand alone: how to sequence practices in a cascade to support student investigations – STEM teaching tool #3

Science and engineering practices should strongly shape instruction—and be integrated with disciplinary core ideas and cross-cutting concepts. Some people might treat the practices as “stand alone” activities to engage students, but research shows that it is more effective to think about designing instruction as a cascade of practices. Practices should be sequenced and intertwined in different ways to support students in unfolding investigations.

What is meant by engaging youth in scientific modeling? - STEM teaching tool #8

A model is a representation of an idea or phenomenon that otherwise may be difficult to understand, depict, or directly observe. Models are integral to the practice of science and are used across many disciplines in a variety of ways. Scientists develop, test, refine, and use models in their research and to communicate their findings. Helping students develop and test models supports their learning and helps them understand important aspects of how science and engineering work.

Beyond a written C-E-R: supporting classroom argumentative talk about investigations – STEM teaching tool #17

Argumentation, a central scientific practice, relies on the coordination of claims, evidence, and reasoning (C-E-R). C-E-R scaffolds can help students compose a written argument for an investigation. However, there are additional important dimensions to argumentation beyond individually written claims. Classroom discussions that require students to make evidence-based claims and collectively build understanding also reflect argumentation. Several types of discussions can be used and can help build a supportive classroom culture.

Why should students learn to plan and carry out investigations in science and engineering? - STEM teaching tool #19

The NRC Framework for K-12 Science Education specifies eight science and engineering practices to be incorporated into science education from kindergarten through twelfth grade. One of these is planning and carrying out investigations. Although many existing instructional models and curricula involve engaging students in planned investigations, this tool will help you think about ways you can promote student agency by having them plan and conduct science investigations.

How can assessments be designed to engage students in the range of science and engineering practices? - STEM teaching tool #26

The new vision for K-12 science education calls for engaging students in three-dimensional science learning. This approach requires us to figure out new ways to assess student learning across these multiple dimensions—including the eight science and engineering practices. But there aren't many assessment tasks that require students to apply their understanding of core ideas using practices. In this tool, we describe how to use "task formats" to guide the development of such items. The formats can also spark ideas for designing classroom instruction.

Integrating science practices into assessment tasks – STEM teaching tool #30

This detailed and flexible tool suggests activity formats to help teachers create three-dimensional assessments based on real-world science and engineering practices. In response to this felt need being expressed among educators, researchers at the Research + Practice Collaboratory have developed a series of "task format" tables, which suggest different possible templates for student activities that integrate real-world science and engineering practices with disciplinary core ideas. This tool also combines two of the Research + Practice Collaboratory's major focuses: formative assessment and engaging learners in STEM practices. This tool offers between four and eight possible task formats for each of the science and engineering practices listed in the Next Generation Science Standards. It can be a great way for educators to brainstorm new activities or to adapt their existing lesson plans to this new three-dimensional vision.

Engaging students in computational design during science investigations – STEM teaching tool #56

Inquiry in science has become increasingly computational over the past several decades. The broad availability of computational devices, sensor networks, visualizations, networking infrastructure, and programming have revolutionized the way science and engineering investigations are carried out. Computational thinking practices enable unique modes of scientific inquiry that allow scientists to create models and simulations to generate data, and to understand and predict complex phenomena. K-12 science classrooms are natural contexts in which students can engage in computational thinking practices during their investigations.

Designing productive uncertainty into investigations to support meaningful engagement in science practices – STEM teaching tool #60

We want students to engage from the earliest ages in science and engineering practices with sincere curiosity and purpose. Science investigations can be viewed as “working through uncertainty.” However, 3D instructional materials often try to support engagement in science practices by making them very explicit and scaffolding the process to make it easy to accomplish—arguably, too easy. An alternative approach that emphasizes productive uncertainty focuses on how uncertainty might be strategically built into learning environments so that students establish a need for the practices and experience them as meaningful ways of developing understanding.

Crosscutting concepts

A Framework for K-12 Education identifies seven concepts that bridge disciplinary boundaries. These concepts provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world.¹ These crosscutting concepts are:

1. Patterns – guide organization and classification, prompt questions about relationships and the factors that influence them.
2. Cause and effect: mechanisms and explanations – a major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across contexts and used to predict and explain events in new contexts.
3. Scale, proportion, and quantity – in considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.
4. Systems and system models – Defining systems under study provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. Energy and matter: flows, cycles, and conservation – Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.
6. Structure and function – The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
7. Stability and change – conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

STEM teaching tools develop briefs to assist STEM teachers with issues that arise in the teaching of STEM. Here are some briefs that address scientific practices. All of these can be found at www.stemteachingtools.org/tools

Prompts for integrating crosscutting concepts into assessment and instruction – STEM teaching tool #41

This set of prompts is intended to help teachers elicit student understanding of crosscutting concepts in the context of investigating phenomena or solving problems. These prompts should be used as part of a multi-component extended task. These prompts were developed using the Framework for K-12 Science Education and Appendix G of the Next Generation Science Standards, along with relevant learning sciences research.

The planning and implementation of instruction in your classroom should allow your students multiple and sustained opportunities to learn disciplinary core ideas through the science and engineering practices, as well as using appropriate crosscutting concepts as lenses to understand the disciplinary core idea and its relationship to other core ideas.

Planning Guidance for Culturally and Linguistically Responsive Instruction

“Equity in science education requires that all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices; with access to quality space, equipment, and teachers to support and motivate that learning and engagement; and adequate time spent on science. In addition, the issue of connecting to students’ interests and experiences is particularly important for broadening participation in science.”¹⁷

In order to ensure our students from marginalized cultures and languages view themselves as confident and competent learners and doers of science within and outside of the classroom, educators must intentionally plan ways to counteract the negative or missing images and representations that exist in our curricular resources. The guiding questions below support the design of lessons that validate, affirm, build, and bridge home and school culture for learners of science:

Validate/Affirm: How can you design your classroom to intentionally and purposefully legitimize the home culture and languages of students and reverse the negative stereotypes regarding the science abilities of students of marginalized cultures and languages?

Build/Bridge: How can you create connections between the cultural and linguistic behaviors of your students’ home culture and language and the culture and language of school science to support students in creating identities as capable scientists that can use science within school and society?

STEM Teaching tools highlight ways of working on specific issues that arise during STEM teaching. Here are some tools that have been created to guide STEM instruction around the concept of culturally and linguistically responsive instruction. All of these can be found at www.stemteachingtools.org/tools

How can we promote equity in science education? - STEM teaching tool #15

Equity should be prioritized as a central component in all educational improvement efforts. All students can and should learn complex science. However, achieving equity and social justice in science education is an ongoing challenge. Students from non-dominant communities often face "opportunity gaps" in their educational experience. Inclusive approaches to science instruction can reposition youth as meaningful participants in science learning and recognize their science-related assets and those of their communities.

Building an equitable learning community in your science classroom – STEM Teaching Tool #54

Equitable classroom communities foster trusting and caring relationships. They make cultural norms explicit in order to reduce the risk of social injuries associated with learning together. Teachers are responsible for disrupting problematic practices and developing science classroom communities that welcome all students into safe, extended science learning opportunities. However, this is tricky work. This tool describes a range of classroom activities designed to cultivate communities that open up opportunities for all students to learn.

How can you advance equity and justice through science teaching? - STEM teaching tool #71

Inequities are built into the systems of science education such that “students of color, students who speak first languages other than English, and students from low-income communities... have had limited access to high-quality, meaningful opportunities to learn science.” Intersecting equity projects can guide the teaching and learning of science towards social justice. Science educators who engage in these projects help advance Indigenous

self-determination (details) and racial justice by confronting the consequences of legacies of injustice and promoting liberatory approaches to education.

Focusing science and engineering learning on justice-centered phenomena across PK-12 – STEM Teaching tool #67

In the Framework vision for science education, students engage in active investigations to make sense of natural phenomena and analyze and build solutions to problems. Basing these investigations on justice-centered phenomena can be a powerful and rightful way to support science and engineering learning. Justice-centered investigations can open up important opportunities for students to engage in projects that support equity for communities and to see how the application of science and engineering are fundamentally entwined with political and ethical questions, dimensions, and decisions.

Teaching STEM in ways that respect and build upon indigenous peoples' rights – STEM teaching tool #10

Indigenous ways of knowing are sometimes thought to be in opposition to and detrimental to the learning of Western Science or STEM. Consequently, indigenous ways of knowing are rarely engaged to support learning. If STEM learning is to be meaningful and transformative for Indigenous youth, respecting Indigenous peoples' rights and related critical issues, including Indigenous STEM, settler-colonialism, and decolonization, must be understood and explicitly addressed in Indigenous youths' informal and formal STEM learning experiences.

How can formative assessment support culturally responsive argumentation in a classroom community? - STEM teaching tool #25

Argumentation has long been seen as an important practice in science and thus in science education. Formative assessment can be used to help students value the contributions and perspectives of others as they engage in argumentation to make sense of natural phenomena. Educators can use these strategies to help foster argumentation that is culturally responsive, meaning it draws from and respects students' cultural resources, backgrounds, and personal experiences. Culturally responsive formative assessment happens within a community of learners where the teacher has cultivated explicit norms for increasing student-centered discourse, making decisions for their own purposes through democratic processes, and using clear guidelines for maintaining mutual respect.

Engaging English learners in science and engineering practices – STEM teaching tool #27

Routinely engaging all students in the practices of science and engineering is a crucial fixture of the new vision for K-12 science education. The practices can be seen as a barrier to participation for English Learners (ELs), or they can be viewed as an opportunity to provide rich instruction that builds science-related competencies and identities. Certain elements of the practices and related instructional approaches can be beneficial for students learning science while also learning the language of instruction.

How can I promote equitable sensemaking by setting expectations for multiple perspectives? - STEM teaching tool #47

In a phenomena-focused, 3D approach to science learning, students use science practices to consider each other's ideas based on available interpretations and evidence. To promote deep and equitable learning, plan purposefully to ensure that the various perspectives that students bring to making sense of phenomena are solicited, clarified, and considered. It is important to support students as they develop a shared understanding of the different perspectives in the group.