NEW MEXICO
Public Education Department

New Mexico Instructional Scope
MS Physical Science Guide

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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 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.

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

<u>Why:</u> 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.

<u>How:</u> 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 following[2]:

- 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.
    - 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?

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

- 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 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

[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.

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 Tools[6]:

- 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,
    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.

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

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: Energy
PS3-1
PS3-2
PS3-3
PS3-4
PS3-5

Students who demonstrate understanding can:

MS-PS3-1. **Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]

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
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	**PS3.A: Definitions of Energy** • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	**Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Connections to other DCIs in this grade-band:
MS.PS2.A

Articulation of DCIs across grade-bands:
4.PS3.B ; **HS.PS3.A** ; **HS.PS3.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. *(MS-PS3-1)*
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS3-1)

Mathematics -

MP.2	Reason abstractly and quantitatively. (MS-PS3-1)
6.RP.A.2	Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship. *(MS-PS3-1)*
7.RP.A.2	Recognize and represent proportional relationships between quantities. (MS-PS3-1)
8.EE.A.1	Know and apply the properties of integer exponents to generate equivalent numerical expressions. (MS-PS3-1)
8.EE.A.2	Use square root and cube root symbols to represent solutions to equations of the form x2 = p and x3 = p, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that √2 is irrational. *(MS-PS3-1)*
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-PS3-1)

Grade	*NGSS Discipline*
MS	**Physical Science 3.1**
PS3-1	**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 8.1: Contact Forces -Why do things sometimes get damaged when they hit each other?
https://www.openscied.org/8-1-contact-forces-download/

Millions of phones are damaged a year in our country, and many of us have experienced such damage firsthand. We have a lot of experiences where a collision between two objects causes damage and also experiences where it surprisingly does not. We model what we think might happen at the moment of impact and a split second after a collision where something breaks and a collision where something doesn't break. We consider some of the factors that could have made a difference in the outcomes of these collisions. This motivates us to create a Driving Question Board (DQB) and brainstorm possible investigations we could do in order to answer our questions.

The Drinking Bird
Description: The drinking bird is a toy heat engine. The source of energy in this phenomenon is a mystery to most students. It is said that Albert Einstein and his wife Elsa were fascinated with this toy when they visited Shanghai in the 1920's.

Video Example: The Drinking Bird — The Wonder of Science

Coupled Pendulum
Description: The coupled pendulum can be created with either string or a spring connecting the two pendulums. With each swing energy is transferred from one pendulum to the other. If the pendulums both have the same length one pendulum comes to a complete stop before alternating motion. This phenomenon can be used to show balanced and unbalanced forces, how motion can be used to predict future motion, and the conservation of energy.

Video Example: Coupled Pendulum — 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-PS3-1 Assessment - Bowling Balls from Wonder of Science

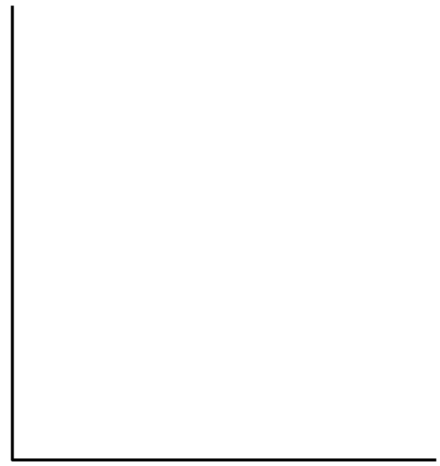
Todd is playing in the garage with his younger sister Jane. He decides to play with 2 bowling balls. One is his, the other is Jane's. He notices that even though they are the same size, Jane's ball is lighter than his. He rolls both balls into the recycling bin, and it does not move as far with Jane's ball as it does with his. He does this five times with both balls and records the distance the box moved each time.

Explain how Todd's data describes the relationship between Mass and Kinetic Energy.

Trials	Distance Moved (Box)	
	Jane's Ball	Todd's Ball
1	0.5m	1.2m
2	0.6m	1.4m
3	0.6m	1.3m
4	0.5m	1.3m
5	0.6m	1.4m
Average		

Construct a bar graph of the average distance for each ball using Todd's data.

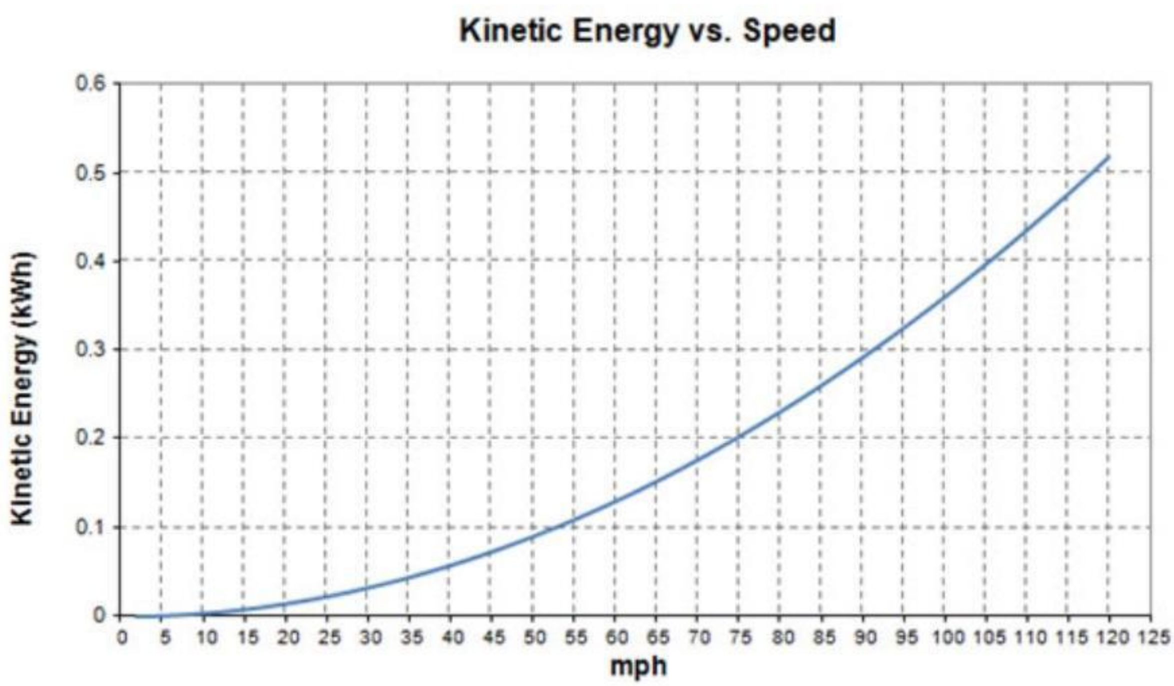
Average Distance Bowling Ball moved Box



Jane's Ball Todd's Ball

Use Evidence from graph C to support a claim that an increase in velocity causes an increase in kinetic energy.

Graph C



http://www.solarjourneyusa.com/EVdistanceAnalysis5.php

Universal Supports	Targeted Supports

	● **Layer 1** - Students should be able to use graphical displays to organize data for the mass, speed, and kinetic energy of the object as well as organize the data in a way that facilitates analysis and interpretation. Students should be able to use the graphical display to identify that kinetic energy can either increase if either the mass and/or the speed of the object increases or decrease if either the mass and/or the speed of the object decreases. Students should be able to use the analyzed data to describe: 1. The relationship between kinetic energy and mass as a linear proportional relationship (KE ∝ m) because the kinetic energy doubles as the mass of the object doubles or the kinetic energy halves as the mass of the object halves. 2. The relationship between kinetic energy and speed as a nonlinear (square) proportional relationship (KE ∝ v2) because the kinetic energy quadruples as the speed of the object doubles and the kinetic energy decreases by a factor of four as the speed of the object is cut in half.	● **Layer 2** - Be prepared to support students in creating and interpreting the graphs that show the relationship between kinetic energy and mass and kinetic energy and speed.

Common Misconceptions

- The more mass in a pendulum bob, the faster it swings.
- Energy is found only in living objects.
- Energy is a force.
- Energy is associated only with movement.
- Energy is a fuel.
- Energy is a substance or fluid.
- Energy is a product of an activity.
- Energy is truly lost in many energy transformations.
- Things “use up” energy.
- Energy is confined to some particular origin, such as what we get from food or what the electric company sells.
- An object at rest has no energy.
- Energy is a “thing.” This is a fuzzy notion, probably because of the way we talk about newton-meters or joules. It is difficult to imagine an “amount” of an abstraction.
- The terms “energy” and “force” are interchangeable.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

Ask students: What knowledge and experiences have you had that might help us as a class explain energy?

Build and Bridge:

Ask students: Why would it be important for you or your community to understand kinetic energy ?

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-PS3-2. **Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*]

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
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 a model to describe unobservable mechanisms.	**PS3.A: Definitions of Energy** • A system of objects may also contain stored (potential) energy, depending on their relative positions. **PS3.C: Relationship Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	**Systems and System Models** • Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.

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

Articulation of DCIs across grade-bands:
HS.PS2.B ; **HS.PS3.B** ; **HS.PS3.C**

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-PS3-2)*

Grade	*NGSS Discipline*
MS	**Physical Science 3.2**
PS3-2	**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 8.3: Forces at a Distance - How can a magnet move another object without touching it? https://www.openscied.org/8-3-forces-distance-download/ A speaker system with a magnet and a coil of wire moves back and forth without the parts touching. We dissect a store bought speaker and then build a homemade speaker. We develop an initial model to describe how interactions between parts of a speaker system cause sound without touching each other. Finally, we generate questions for our Driving Question Board (DQB) using a cause-effect scaffold that we will return to throughout the unit. Magnetic Cannon Description: The magnetic cannon contains four spaced neodymium magnets in a channel. Two balls bearings are placed between each ball bearing. When a new ball bearing is introduced a transfer of energy occurs and the final ball bearing leaves with a higher initial velocity than the first. This is a great phenomenon for studying transfer of momentum and the energy of an object based on its position within a magnetic field.

Video Resources: [Magnetic Cannon — The Wonder of Science]

The Gravity Light
Description: The Gravity Light converts potential energy that is stored in a weight into light. The principles involved in this design are very similar to the principles in a cuckoo clock, with the potential energy of the weight being converted to solar energy rather than kinetic energy. Gravity Lights can replace kerosene lights in the developing world with a safe alternative. The phenomenon can be used to illustrate the conversion of potential gravitational energy into other forms of energy. More importantly it conveys the message of sustainability and social responsibility.

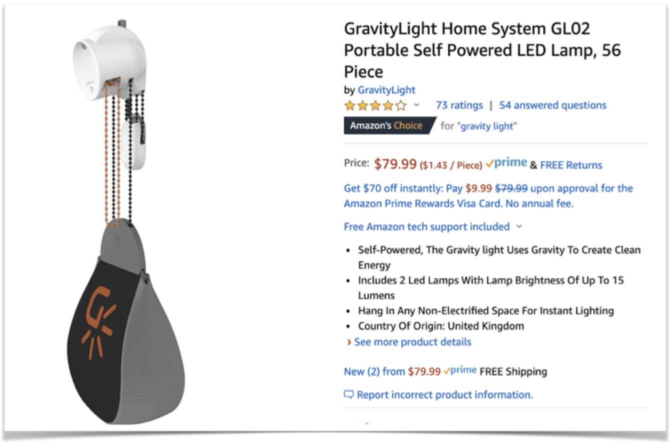
Video Resource: [The Gravity Light — The Wonder of Science]

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-PS3-2 Assessment - The Gravity Light from Wonder of Science

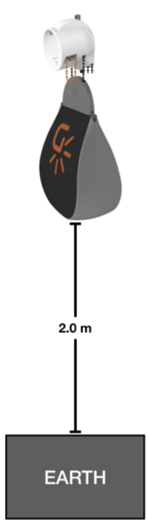
Background:



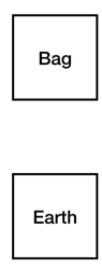
Amazon is currently selling the GravityLight Self Powered LED for $79.99

According to the website
"GravityLight is a unique and innovative device that generates light from gravity. This portable hanging lamp is simple to set up and provides instant light in any non-electrified space. It includes 2 LED lamps providing lamp brightness of up to 15 lumens. No batteries, no charging required."
(Source)

Operation:
The GravityLight is fairly easy to operate. The entire light assembly is hung in an area that requires light. Up to 26 pounds of material (e.g. rocks) are loaded into the bag at the bottom of the assembly. A pulley is then used to raise the loaded bag a couple of meters off the ground. As the bag falls some of the kinetic energy in the gear assemblage is converted to light energy in the LED. The GravityLight provides light for up to 20 minutes and offers a replacement to kerosene lights that are used in areas with no electricity.



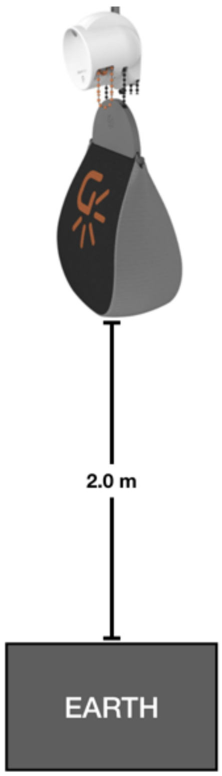
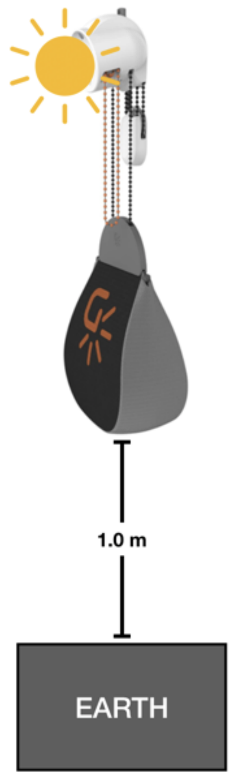
1. Draw and describe the gravitational forces acting on both the bag and the Earth in the initial setting shown to the left.



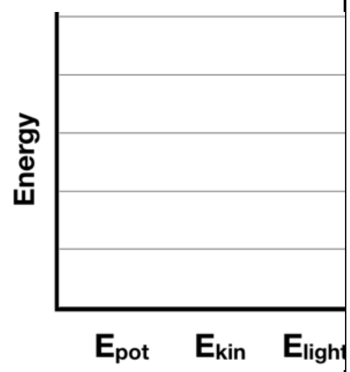
2. What energy is found in the Light/Earth system before it moves? (circle all that apply)

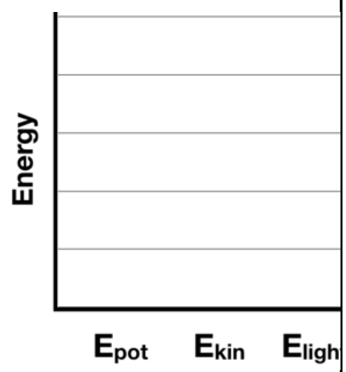
Potential energy Kinetic energy Light energy

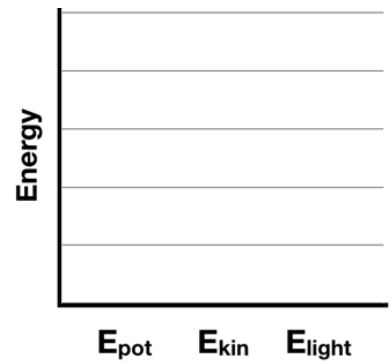
3. Complete the following table. For the energy bar charts assume that the system contains both the Earth and the GravityLight. $\mathbf{E_{pot}}$ represents the potential energy in the system. $\mathbf{E_{kin}}$ represents the kinetic energy in the gears of the GravityLight. **E_{light}** represents the light produced by the gravity light.

Time	0 minutes	10 minutes	20 minutes
Image			
Gravitational forces (label and describe)	Bag Earth	Bag Earth	

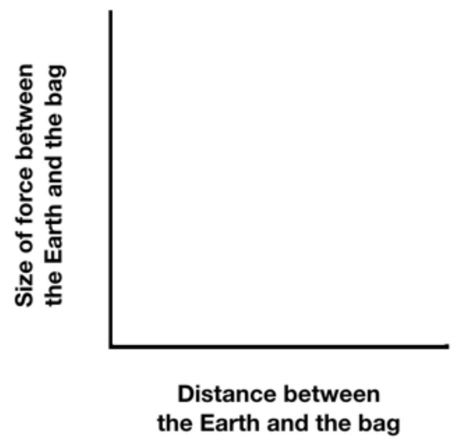
Energy bar chart for the light/Earth system.







4. Draw a line on the following graphs that represents the relationship between the Earth and the bag. Assume the light and Earth are in the system.



5. The GravityLight seems to be providing free energy without electricity or fuel. Where is the additional input of energy into the system coming from? Explain your thinking.

Universal Supports	**Targeted Supports**
• Layer 1 - Students should be able to develop a model in which they identify the relevant components (a system of two stationary objects that interact, forces (electric, magnetic, or gravitational) through which the two objects interact, distance between the two objects, and the potential energy of the system). Students should be able to use this model to identify and describe the relationship between the components, including	• Layer 2 - Provide extra support for hands-on activities to show these relationships. Reteach the vocabulary to help students make sense of this vocabulary in terms of what they know in real world vocabulary.

1. When the two objects interact at a distance, each one exerts a force on the other that can cause energy to be transferred to or from an object
2. As the relative position of two objects (neutral, charged, magnetic) changes, the potential energy of the system (associated with interactions via electric, magnetic, and gravitational forces) changes (e.g., when a ball is raised, energy is stored in the gravitational interaction between the Earth and the ball).

Students should use the model to explain the idea that the amount of potential energy in a system of objects changes when the distance between stationary objects interacting in the system changes because a force has to be applied to move two attracting objects farther apart, transferring energy to the system OR a force has to be applied to move two repelling objects closer together, transferring energy to the system.

Common Misconceptions

- A charged object can only attract other charged objects.
- The electrostatic force between two charged objects is independent of the distance between them.
- Energy is a thing. This is a fuzzy notion, probably because of the way we talk about newton-meters or joules. It is difficult to imagine an amount of abstraction.
- The terms “energy” and “force” are interchangeable.
- An object at rest has no energy.
- Things “use up” energy.
- Energy is confined to some particular origin, such as what we get from food or what the electric company sells.
- Energy is truly lost in many energy transformations.
- There is no relationship between matter and energy.
- The only “natural” motion is for an object to be at rest.
- If an object is at rest, no forces are acting on the object.
- Potential energy is a conserved quantity

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

	Validate and Affirm: Ask students: What knowledge and experiences have you had that might help us as a class explain gravity? Ask students: What knowledge and experiences have you had that might help us as a class explain magnetism? **Build and Bridge:** Ask students: Why would it be important for you or your community to understand how different objects can interact at a distance? 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-PS3-3. **Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

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
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.	**PS3.A: Definitions of Energy** • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **PS3.B: Conservation of Energy and Energy Transfer** • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. **ETS1.A: Defining and Delimiting an Engineering Problem** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. *(secondary)* **ETS1.B: Developing Possible Solutions** • A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. *(secondary)*	**Energy and Matter** • The transfer of energy can be tracked as energy flows through a designed or natural system.

Connections to other DCIs in this grade-band:
MS.PS1.B ; **MS.ESS2.A** ; **MS.ESS2.C** ; **MS.ESS2.D**

Articulation of DCIs across grade-bands:
4.PS3.B ; **HS.PS3.B**

Common Core State Standards Connections:
ELA/Literacy -

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS3-3)*

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS3-3)

Grade	NGSS Discipline
MS	Physical Science 3.3
PS3-3	**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 6.2: Thermal Energy - How can containers keep stuff from warming up or cooling down? https://www.openscied.org/6-2-thermal-energy-download/ I've been buying iced drinks for years using the regular cup, but my drink always warms up and waters down. The designers of the fancy cup claim the cup can keep a drink colder for longer.

We observe an iced drink in a regular cup warming up more quickly compared with an iced drink in a fancy cup. We develop systems models to explain what is happening in the two cups that leads one to be better than the other at maintaining the temperature of the drink. We brainstorm why certain objects are better at keeping things cold or hot by considering features of each object's design. We ask questions about design features and other factors that influence how well an object can keep something hot or cold, and we generate a list of investigations to test these factors.

Aerogels - World's Lightest Solids
Description: Aerogels are a group of synthetic materials that are incredibly light and also amazing insulators. They have numerous applications such as insulators in electronics. Aerogels were used as thermal insulators in the Mars Rover and also act to filter space dust. This phenomenon could be used as an application of chemical engineering or as an example of a thermal insulators.

Video Resources: [Aerogels - World's Lightest Solids — The Wonder of Science](#) or [How It's Made Aerogel](#)

Earthships

Description: An Earthship is a passive solar house that is designed to be off the electrical grid. It is generally constructed with natural and recycled materials. Much of the structure of the house is made with recycled tires that are filled with dirt. Thermal mass from the dirt, solar energy from the Sun, and cross-ventilation are used to keep the temperature within the house in a comfortable zone. This phenomenon can be used study thermal energy transfer, energy conservation, and human sustainability.

Video Resources: [Earthships — The Wonder of Science]

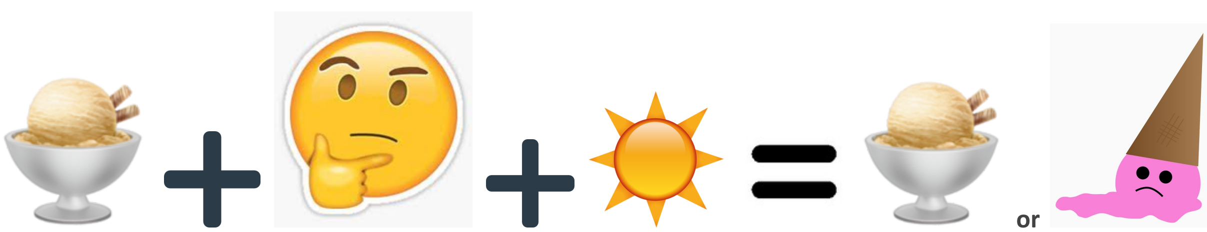
Classroom Assessment Items

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-PS3-3 Assessment - Insulating Ice Cream Project Edited (NY)] from Wonder of Science

KEEP IT COLD!

ENGINEERING DESIGN CHALLENGE: INSULATING ICE CREAM



Guiding Question: How can we limit the transfer of thermal energy to keep items cold while it's hot outside?

Performance Expectation: Apply scientific principles to design, construct, and test a device that minimizes thermal energy transfer.

Scenario: You own an ice cream company in Dubai and you want to begin to offer delivery to increase your profits and grow your business. In order to ship during the intense heat in the middle of summer using motorcycle delivery service, you will have to develop your own insulated container.

Task: Design an insulated packing container that will keep three small containers of ice cream frozen during transport AND fit in the container on the back of a delivery motorcycle in the heat of a Dubai summer.

Criteria: These are the *expectations* your design must meet to be successful.

- Your shipping container must minimize the transfer of thermal energy, i.e. keep the ice cream from warming up, as the Swiss try to do with their glacier. Wrapping a Glacier in a Blanket
- Background information on thermal energy and heat transfer:
  Heat Transfer: Crash Course Engineering #14
  Potential and Kinetic Energy

https://www.youtube.com/watch?v=NuBv5H1cYyE

https://www.youtube.com/watch?time_continue=407&v=xGKg3Tso4v8

- Your shipping container must keep the ice cream container inside from being squashed or sliding around, see this video as evidence to the importance of this.

Constraints: These are the *limitations* that you need to consider.

- You will be given three, individual serving sized 125 mL of cold ice cream or ice, depending on number of members.
  - Height of the ice cream cup = 7 cm
  - Diameter of the lid = 6.8 cm
  - Diameter of the base of the ice cream cup = 5.4 cm
- Your container exterior must be made from normal, thin cardboard to reduce costs.
- In order to maximize delivery, your container will be able to fit into a 18cm x 27cm x 33cm box.
- Container must be watertight to avoid condensation damage.

- No additional "wet" items should be within the container, such as water, ice, or ice packs, including gels and dry ice.
- Container must be easy-to-open to get ice cream inside and to measure temperature.
- No premade insulating containers, such as an insulated lunch bag.
- You will record the ice cream temperature at the beginning of the class and the end of the class on the testing day.
- You can eat your ice cream once it is "delivered" at the end of the testing day.

Evaluation: You will be assessed on your ability to...

- ❏ Develop a solution that meets the criteria and constraints
- ❏ Use evidence to identify the most effective design
- ❏ Use the CER format to write a science argument about what the most effective design is

Click here to see the rubric!

Universal Supports	Targeted Supports
• Layer 1 - Given a problem to solve that requires either minimizing or maximizing thermal energy transfer, students should be able to design and build a solution to the problem. In the designs, students: 1. Identify that thermal energy is transferred from hotter objects to colder objects. 2. Describe different types of materials used in the design solution and their properties (e.g., 3. thickness, heat conductivity, reflectivity) and how these materials will be used to minimize or maximize thermal energy transfer. 4. Specify how the device will solve the problem.	• Layer 2 - Provide opportunities for students to work in structured peer groups to provide support for students in need of support. This could also be provided through one-on-one teacher support or small group reteaching and problem solving.

Common Misconceptions

- Temperature is a property of a particular material or object——metal is naturally cooler than plastic.
- The temperature of an object depends on its size.
- Heat and cold are different, rather than being opposite ends of a continuum.
- Ice cannot change temperature.
- Objects that readily become warm, are good conductors of heat, do not readily become cold.
- Expansion of matter is due to expansion of particles rather than to increased particle spacing.
- Particles of solids have no motion.

- Melting/freezing and boiling/condensation are often understood only in terms of water.
- Particles are viewed as mini-versions of the substances they comprise.
- Particles are often misrepresented in sketches. No differentiation is made between atoms and molecules.
- Particles misrepresented and undifferentiated in concepts involving elements, compounds, mixtures, solutions and substances.
- Frequent disregard for particle conservation and orderliness when describing changes.
- Batteries have electricity inside them.
- Energy is a thing. This is a fuzzy notion, probably because of the way we talk about newton-meters or joules. It is difficult to imagine an amount of abstraction.
- The terms “energy” and “force” are interchangeable.
- Cold flows in the opposite direction than heat

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

Ask students: What experiences have you had with trying to keep food or drinks hot or cold? What did you use and why did you use it?

Build and Bridge:

Ask students: Why would it be important for you or your community to understand how objects are kept hot or cold for extended periods of time?

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-PS3-4. **Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

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

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

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

PS3.A: Definitions of Energy

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer

- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.

Crosscutting Concepts

Scale, Proportion, and Quantity

- Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Connections to other DCIs in this grade-band:
MS.PS1.A ; **MS.PS2.A** ; **MS.ESS2.C** ; **MS.ESS2.D** ; **MS.ESS3.D**

Articulation of DCIs across grade-bands:
4.PS3.C ; **HS.PS1.B** ; **HS.PS3.A** ; **HS.PS3.B**

Common Core State Standards Connections:
ELA/Literacy -

RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS3-4)
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *(MS-PS3-4)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (MS-PS3-4)
6.SP.B.5	Summarize numerical data sets in relation to their context. *(MS-PS3-4)*

Grade	*NGSS Discipline*
MS	**Physical Science 3.4**
PS3-4	**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 6.2: Thermal Energy - How can containers keep stuff from warming up or cooling down? https://www.openscied.org/6-2-thermal-energy-download/ I've been buying iced drinks for years using the regular cup, but my drink always warms up and waters down. The designers of the fancy cup claim the cup can keep a drink colder for longer.

We observe an iced drink in a regular cup warming up more quickly compared with an iced drink in a fancy cup. We develop systems models to explain what is happening in the two cups that leads one to be better than the other at maintaining the temperature of the drink. We brainstorm why certain objects are better at keeping things cold or hot by considering features of each object's design. We ask questions about design features and other factors that influence how well an object can keep something hot or cold, and we generate a list of investigations to test these factors.

Ice-cutting Experiment

Description: In this experiment, by Derek Muller at Veritasium, a copper wire and fishing string are attached to weights and placed over a block of ice. An increase in pressure causes the ices to melt below the wire and freeze after. The difference in behavior of the wire and the string are related to the material since metal is a better thermal conductor of heat. This phenomenon can be used in a unit on the particle model and state change. It can also be used to compare the thermal conductivity of different materials.

Video Resources: [Ice-cutting Experiment — The Wonder of Science]

Brinicles

Description: As ocean water freezes into solid ice the remaining saltwater forms into icy "stalactites" that descend into the ocean. This can be used as a phenomenon in an elementary class to show changes in state. In middle and high school the chemistry can be explored more deeply.

Video Resources: [Brinicles — 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.

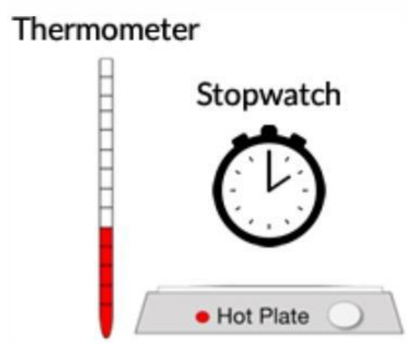
MS-PS3-4 Assessment - Honey vs Maple Syrup from Wonder of Science

Robert is cooking with a recipe that uses both honey and maple syrup. Robert wonders, "If I heat the honey and maple syrup with the same amount of thermal energy, will they both have the same temperature change?"

Robert conducts an experiment to answer his question. To do this experiment, he starts by measuring out an equal mass of room temperature (22 °C) honey and maple syrup.

He has the following equipment:

- A thermometer
- A stopwatch
- A hot plate that has three temperature settings (low, medium, and high). The hot plate is only big enough to heat one substance at a time.



1. Describe how Robert can use the thermometer, stopwatch, and hot plate to answer his question about the temperature change that occurs when heating honey and maple syrup.
2. Explain how the procedure you wrote allows Robert to answer his question.
3. In Robert's experiment, what do you think will happen to the temperature of the honey and maple syrup when they are both heated equally? Explain why you think so in your response.

Universal Supports	Targeted Supports
• Layer 1 - Students should be able to identify the phenomenon and describe the purpose of the investigation, including determining the relationships between the transfer of thermal energy, types of matter, the mass of matter involved in thermal energy transfer, and the change in the average kinetic energy of the particles. Students should be able to develop an investigation plan that describes and collects data and evidence, including the initial and final temperatures of the materials and the types and mass of the matter used in the investigation. This data should provide evidence of proportional relationships between changes in temperature of materials and the mass of those materials and relate the changes in temperature in the sample to the types of matter and to the change in the average kinetic energy of the particles. The investigation plan should address: 1. How the mass of the materials are to be measured and in what units. 2. How and when the temperatures of the materials are to be measured and in what units. 3. Details of the experimental conditions that will allow the appropriate data to be collected to address the purpose of the investigation (e.g., time between temperature measurements, amounts of sample used, types of materials used), including appropriate independent and dependent variables and controls.	• Layer 2 - Students may need support with the graphical representation of their findings, but also may need support with the development of the investigation plan. One way to support this learning could be purposeful small groupings, and opportunities for Q&A periods with the teacher.

Common Misconceptions

- Heat is a substance.
- Heat is not energy.
- Temperature is a property of a particular material or object——metal is naturally cooler than plastic.
- The temperature of an object depends on its size.

- Heat and cold are different, rather than being opposite ends of a continuum.
- Ice cannot change temperature.
- Objects that readily become warm, are good conductors of heat, do not readily become cold.
- Expansion of matter is due to expansion of particles rather than to increased particle spacing.
- Particles of solids have no motion.
- Melting/freezing and boiling/condensation are often understood only in terms of water.
- Particles are viewed as mini-versions of the substances they comprise.
- Particles are often misrepresented in sketches. No differentiation is made between atoms and molecules.
- Particles misrepresented and undifferentiated in concepts involving elements, compounds, mixtures, solutions and substances.
- Frequent disregard for particle conservation and orderliness when describing changes.
- Absence of conservation of particles during a chemical change.
- Batteries have electricity inside them.
- Energy is a thing. This is a fuzzy notion, probably because of the way we talk about newton-meters or joules. It is difficult to imagine an amount of abstraction.
- The terms “energy” and “force” are interchangeable.
- Heat is a substance that flows in and out of matter, not a transfer of energy

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

Ask students: What experiences have you had with trying to figure something out? What approaches have you used?
Ask students: What knowledge and experiences have you had that could help the class figure out how thermal energy moves?

Build and Bridge:
Ask students: Why would it be important for you or your community to understand how heat energy moves over time?

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-PS3-5. **Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.** [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [*Assessment Boundary: Assessment does not include calculations of energy.*]

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
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed worlds. • Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. - ***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	**PS3.B: Conservation of Energy and Energy Transfer** • When the motion energy of an object changes, there is inevitably some other change in energy at the same time.	**Energy and Matter** • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).

Connections to other DCIs in this grade-band:
MS.PS2.A

Articulation of DCIs across grade-bands:
4.PS3.C ; **HS.PS3.A** ; **HS.PS3.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. *(MS-PS3-5)*
WHST.6-8.1	Write arguments focused on discipline content. *(MS-PS3-5)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (MS-PS3-5)
6.RP.A.1	Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities. *(MS-PS3-5)*
7.RP.A.2	Recognize and represent proportional relationships between quantities. *(MS-PS3-5)*
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-PS3-5)*

Grade	*NGSS Discipline*
MS	**Physical Science 3.5**
PS3-5	**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 6.2: Thermal Energy - How can containers keep stuff from warming up or cooling down? https://www.openscied.org/6-2-thermal-energy-download/ I've been buying iced drinks for years using the regular cup, but my drink always warms up and waters down. The designers of the fancy cup claim the cup can keep a drink colder for longer.

We observe an iced drink in a regular cup warming up more quickly compared with an iced drink in a fancy cup. We develop systems models to explain what is happening in the two cups that leads one to be better than the other at maintaining the temperature of the drink. We brainstorm why certain objects are better at keeping things cold or hot by considering features of each object's design. We ask questions about design features and other factors that influence how well an object can keep something hot or cold, and we generate a list of investigations to test these factors.

Amazing Rube Goldberg Machines
Description: Rube Goldberg machines are named after American cartoonist Rube Goldberg who drew complicated steps involved in doing a fairly simple task (like pouring milk in a glass). Students can study these machines, or build their own, to show how energy can be converted through a series of interactions. In lower elementary classes they might be shown or built to show how pushes or pulls can change the motion of objects. As they move through school they should start to identify specific collisions, interactions, and conversions of energy.

Video Resources: [Amazing Rube Goldberg Machines — The Wonder of Science]

Giant Newton's Cradle
Description: The coupled pendulum can be created with either string or a spring connecting the two pendulums. With each swing energy is transferred from one pendulum to the other. If the pendulums both have the same

length one pendulum comes to a complete stop before alternating motion. This phenomenon can be used to show balanced and unbalanced forces, how motion can be used to predict future motion, and the conservation of energy.

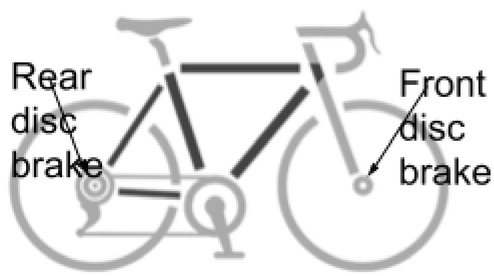
Video Resources: [Giant Newton's Cradle — The Wonder of Science]

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.

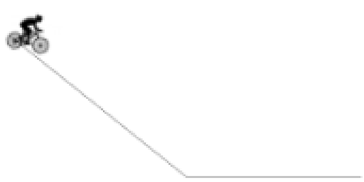
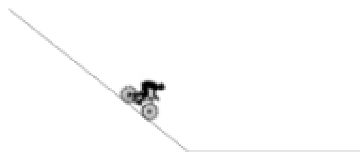
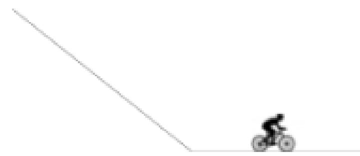
[MS-PS3-5 Assessment - Changes in Energy on a Bicycle] from Wonder of Science

Paul exits his house, halfway up a large hill, and hops on his bike to ride down to a friend's house. As he approaches the bottom of the hill, Paul notices his shoelace is untied and he quickly applies the brakes to come to a loud, squealing stop. As he gets off his bike to tie his shoe, his arm brushes against the center of the bike wheel where the disc brake is. "Oww!" he exclaims, "It's hot!"



Part 1. Modeling the Situation

1. Use graphical representations to show how the type of energy experienced by the cyclist and the amount of each type of energy changes at each of the following points in his ride.

<table>
<tr><td>(A) Stopped at the starting point on the hill</td><td>(B) As he travels down the hill and first starts to apply the brakes</td><td>(C) At the bottom of the hill when he has stopped</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Directions: Show the energy transfer (flow) that occurs in the system using pie charts or bar graphs that takes into account how you show the total amount of energy in the system.</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

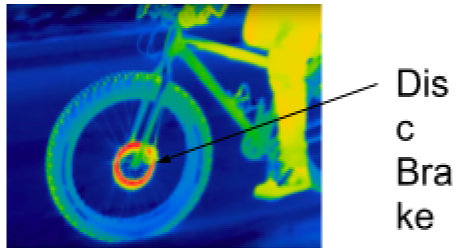
2. How would **increasing the mass** of the cyclist affect the **amount** of total energy in the system?

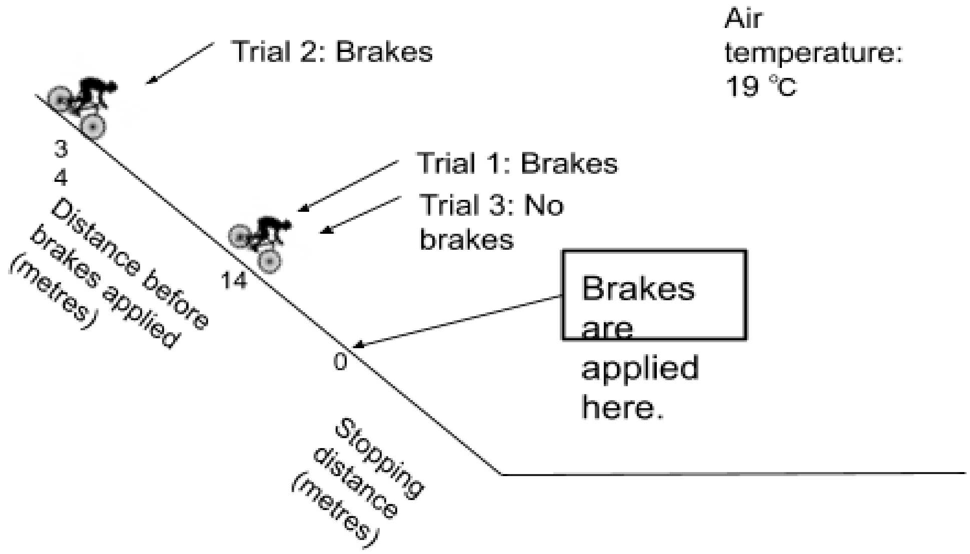
3. Identify which **force(s)** cause an increase or decrease to the speed of the cyclist?

Part 2. Planning and Carrying Out an Investigation

Paul set up the following experiment to investigate further. He collected data for himself on the bike and his father, who is exactly double his mass. After each trial, he used a thermal imaging camera to determine the hottest parts of the bike.

- The video https://youtu.be/z2hfVV7odEw shows the investigation.
- The image shows a thermal image of his bike after applying his brakes.





Trial 1 (control).

- Paul starts from outside his house, halfway up the hill.
- He carefully measures the distance before he applies the brakes and the distance it took to stop once the brakes were applied.

Trial 2.

- Paul starts at a *higher* point on the hill.
- He applies the brakes at exactly the same point in his ride as in trial 1 and measures the distance it took to stop once the brakes were applied.

Trial 3.

- Paul repeats the original situation in trial 1 but without ever applying his brakes.
- He measures the distance it took him to coast to a stop without using his breaks.

Mass of Cyclist 1: 40kg (Paul)

Trials	Distance before brakes applied (meters)	Stopping distance (meters)	Temperature of the disc brakes **before each ride** in °C	Temperature of the disc brakes **after stopping** in °C	Maximum Speed (kilometers per hour)
1. Halfway up hill, with brakes	14m	2m	19°C	37°C	20 km/h
2. Higher point on the hill with brakes	34m	6m	19°C	42°C	25 km/h
3. Halfway up hill, without brakes	--	100m	19°C	20°C	20 km/h

Mass of Cyclist 2: 80kg (Paul's father)

Trials	Distance before brakes applied (meters)	Stopping distance (meters)	Temperature of the disc brakes **before each ride** in °C	Temperature of the disc brakes **after stopping** in °C	Maximum Speed (kilometers per hour)
1. Halfway up hill, with brakes	14m	5m	19°C	39°C	20 km/h
2. Higher point on the hill with brakes	34m	15m	19°C	47°C	25 km/h
3. Halfway up hill, without brakes	--	250m	19°C	20°C	20 km/h

4. Analyze the information in the video, pictures and data in the tables above and describe what is happening to **cause his disc brake to get so hot**.

What patterns do you see in the information (video, pictures and data)?	Ranking based on usefulness to answer the question (Least, somewhat, most useful)

Universal Supports	Targeted Supports
• **Layer 1** - Students make a claim about a given explanation or model for a phenomenon. In their claim, students should include the idea that when the kinetic energy of an object changes, energy is transferred to or from that object. Students identify and describe the given evidence that supports the claim, including the change in observable features (e.g., motion, temperature, sound) of an object before and after the interaction that changes the kinetic energy of the object as well as the change in observable features of other objects or the surroundings in the defined system. Students evaluate the evidence and identify its strengths and weaknesses, based on the types of sources, sufficiency (including validity and reliability) of the evidence to make and defend the claim and any alternative interpretations of the evidence and why the evidence supports the given claim. Students use reasoning to connect the necessary and sufficient evidence and construct the argument. Students should be able to describe a chain of reasoning that based on changes in the observable features of the object (e.g., motion, temperature), the kinetic energy of the object changed or	• **Layer 2** - Give students opportunities to present their findings in a variety of ways, either in person or recorded to increase their possibility of showing what they know with ease.

when the kinetic energy of the object increases or decreases, the energy (e.g., kinetic, thermal, potential) of other objects or the surroundings within the system increases or decreases, indicating that energy was transferred to or from the object. Lastly, the student should present oral or written arguments to support or refute the given explanation or model for the given phenomena.

Common Misconceptions

- Temperature is a property of a particular material or object——metal is naturally cooler than plastic.
- The temperature of an object depends on its size.
- Heat and cold are different, rather than being opposite ends of a continuum.
- Ice cannot change temperature.
- Objects that readily become warm, are good conductors of heat, do not readily become cold.
- Particles in solids or in freezing temperatures are not in motion

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

Ask students: What do you think of when you are asked to make an argument? How is this similar to or different from arguments you might have outside of science class?
Ask students: What knowledge and experiences have you had that could help the class figure out how to make an argument about the relationship between an object's motion and energy?

Build and Bridge:
Ask students: Why would it be important for you or your community to understand how energy moves into and out of objects?

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.

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[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.[1]"

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.