Table of Contents

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.

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

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

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

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

Students who demonstrate understanding can:

HS-PS3-1 **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

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

Science and Engineering Practices

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Create a computational model or simulation of a phenomenon, designed device, process, or system.

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

Crosscutting Concepts

Systems and System Models

- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes the universe is a vast single system in which basic laws are consistent.

Connections to other DCIs in this grade-band:
HS.PS1.B ; HS.LS2.B ; HS.ESS1.A ; HS.ESS2.A

Articulation of DCIs across grade-bands:
MS.PS3.A ; MS.PS3.B ;MS.ESS2.A

Common Core State Standards Connections:

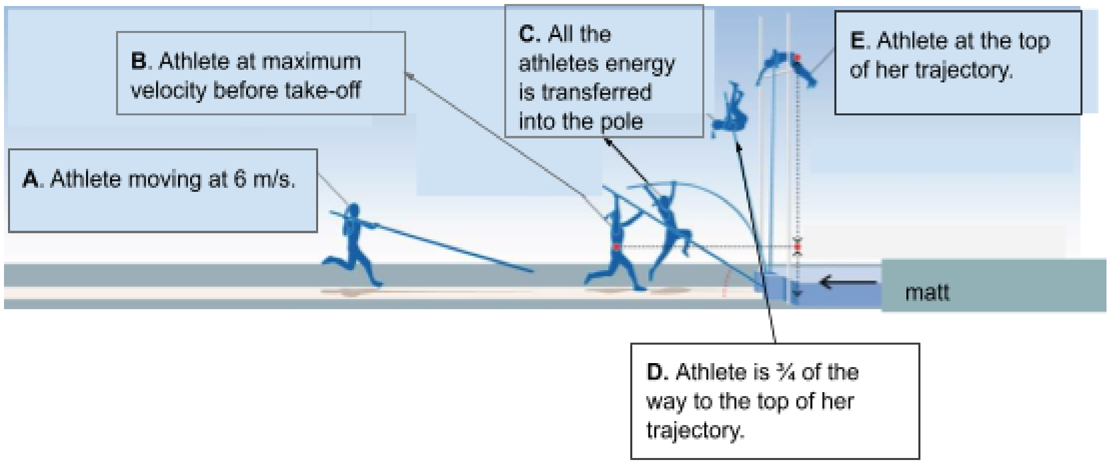
ELA/Literacy -

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-1)*

Mathematics -

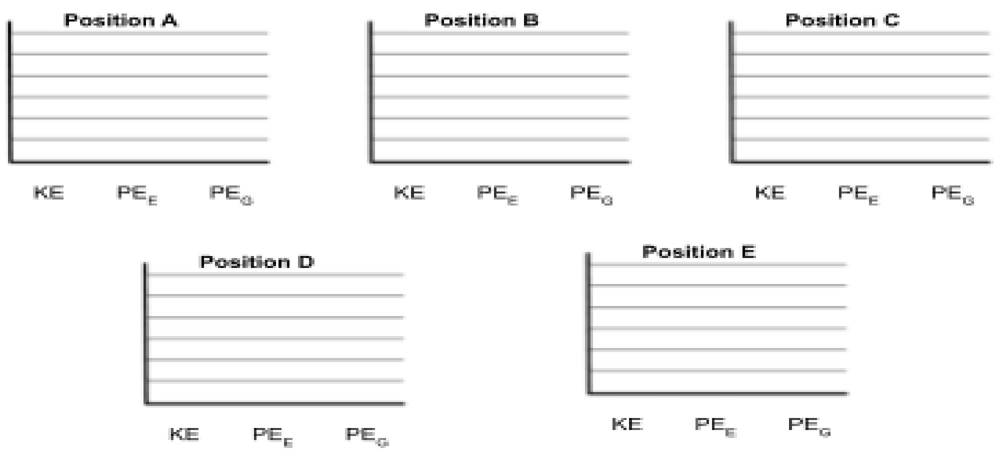
MP.2 Reason abstractly and quantitatively. (HS-PS3-1)
MP.4 Model with mathematics. (HS-PS3-1)
HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1)
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1)

Grade	NGSS Discipline
HS	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.* In 2019, Chloe Cunliffe became the national high school record holder in the pole vault. There is a change in energy as a pole vaulter sprints down the track, plants the pole, and lifts off with enough power to cross over a high bar. ● Chloe Cunliffe Olympic Hopeful ● Play the video several times and in slow motion if possible. Discuss with students and make a list of questions that students may have. ○ For example: what would happen if Chloe ran slower. ○ What would happen if she ran faster? ○ Energy is transferred when pole vaulting. Where does the energy come from? ○ Does the material that the pole is made of matter? ○ Does the mass of the vaulter make a difference in attaining maximum height? **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.* **Pole Vault Energy Transfer** Video of Chloe **Equations**: W = F x d KE = ½ m v^2 PE = m g h P = W / t g = acceleration due to gravity which equals 9.8 m/s^2 1.00 kg = 2.20 pounds Directions: For all calculation questions write the equation you will use, include units with each number, and report all answers to the correct number of significant figures. Use dimensional analysis as needed to convert units.The bolded questions need to be answered in depth with a focus on making connections. 1. Pole vaulting is a sport that requires both a lot of strength and good technique. It is one of the most athletically complex and demanding of all sports competitions. Below is a diagram of an athlete successfully getting over the bar.



Source: Best, & Sataua (2018)

a. Model the athletes energy transformations from point A to point E.

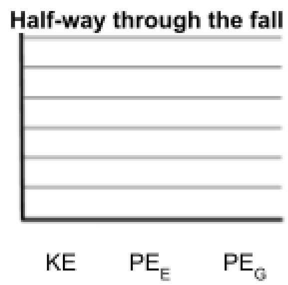


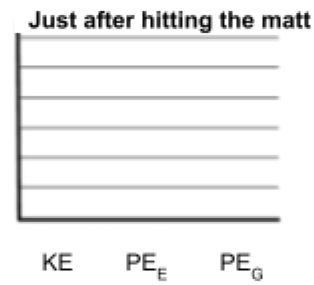
b. On march 17, 2019 Chloe Cunliffe, a senior high school student from West Seattle High School vaulted 4.48 m to earn the position of top female athlete in the United States. (Russel, 2019)

i. If Chloe weighed 108 pounds on the day of the jump, calculate her maximum potential energy. Show all your work including formulas, units and significant figures.

ii. Calculate Chloe's maximum velocity on her approach. Show all your work including formulas, units and significant figures.

c. Model the energy transfer involved when a pole vaulter, such as Chloe, hits the mat after the jump. Be sure to define your system. Explain your diagram.





Sources

Best, R, & Sataua, C. (2018). Pole Vault World Records and Sports Product Innovation. (2018, November 27). Retrieved from Pole Vault World Records and Sports Product Innovation

Russell, Brian (April 6, 2019). "Arcadia Girls — Another HS High For Cunliffe". *Track and Field News*. Retrieved April 6, 2019.

HS-PS3-1 Assessment - Pole Vault Energy Transfer

Universal Supports	Targeted Supports
• Students can use a graphic organizer to write an explanation of how a pole vaulter crosses over a bar using a pole. • Use anchor charts to model how potential energy is changed to kinetic energy and gravitational potential energy. ○ Students can draw a picture of the energy transfer from a runner to the pole showing how elastic potential energy of the pole is changed to kinetic energy and gravitational potential energy. • Incorporate computational equations and a diagram of the vaulter and of the pole as a model by drawing the diagram for the class. • Use manipulatives for each part of the pole vault from start to finish to demonstrate the	• Review the concepts of elastic potential energy with struggling students by providing individual instruction. • Monitor progress and provide assistance as necessary

	transfer of energy from kinetic to elastic potential energy to kinetic and gravitational potential energy.	

Common Misconceptions

- A misconception is that athletes do not rely on physics or mathematics to improve techniques, yet physics and mathematics with technology can improve times and techniques in all athletics.
- Energy is not the same as matter because it does not have shape or form.
- Energy does not disappear, but reduction of energy in one place results in the gain of energy in another.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Show multiple examples of pole vaulters from other cultures or ethnicities
- Discuss the origins of using a pole to cross over a canal in parts of Europe and how the use of a pole evolved into the pole vaulting of today to help in sense making of the phenomonon.
- Include all students in the discussion of pole vaulting. Be mindful of student-athletes who may be familiar with pole vaulting and could lead discussion in technique that is unfamiliar to others. Incorporate forms of energy in each step of the vault.
- Consider cultures that used or still use elastic potential energy in gathering food or hunting. Provide examples of archery equipment or slings.

Students who demonstrate understanding can:

HS-PS3-2. **Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).** [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

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 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS3.A: Definitions of Energy** • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	**Energy and Matter** • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Connections to other DCIs in this grade-band:
HS.ESS2.A ; HS.PS1.A ; HS.PS1.B ; HS.PS2.B

Articulation of DCIs across grade-bands:
MS.PS1.A ; MS.PS2.B ; MS.PS3.A ; MS.PS3.C

Common Core State Standards Connections:
ELA/Literacy -
SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-2)*
Mathematics -
MP.2 Reason abstractly and quantitatively. (HS-PS3-2)
MP.4 Model with mathematics. (HS-PS3-2)

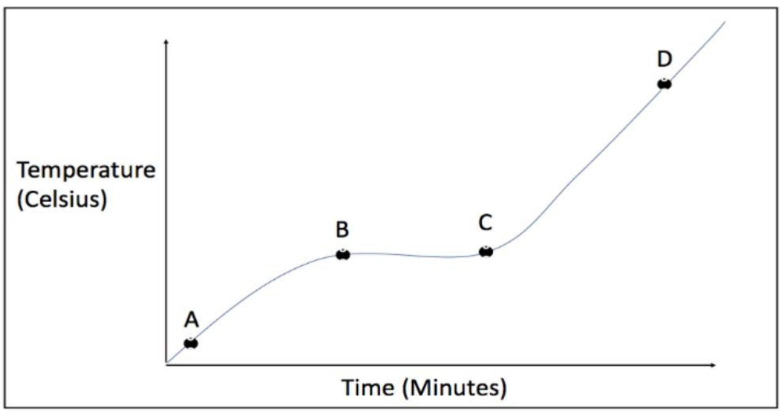
Grade	*NGSS Discipline*
HS	**Physical Science**
PS3-2	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.* [Ice-cutting Experiment — The Wonder of Science] **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.

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.

To investigate how the temperature of ice changes on a hot summer day, Kellie put three thermometers in ice cube tray wells, filled the wells with water, and put the tray in the refrigerator overnight. In the morning, she took the tray outside and recorded the temperature of three ice cubes as well as her observations of what happened to each cube. The average temperature change of the three cubes is reported on the graph below.

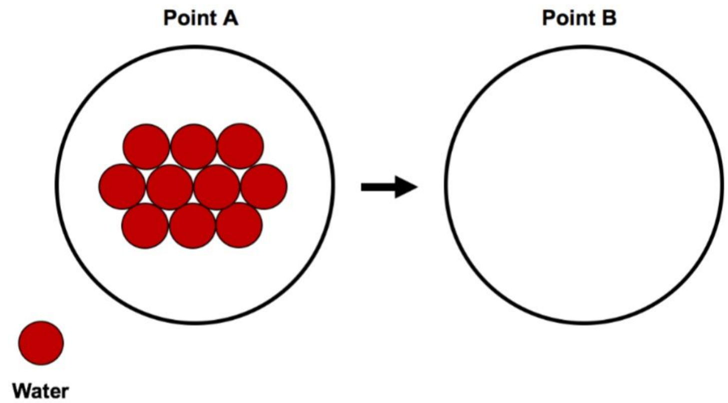


Time Point	Observation
A - B	Mostly solid ice
B - C	Mixture of ice and water
C - D	Mostly liquid water

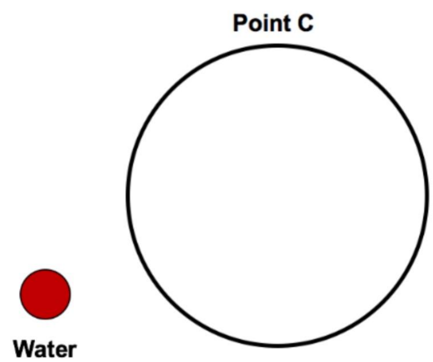
Kellie was curious why the water was sometimes increasing in temperature, while at other times it did not change its temperature but was changing from solid to liquid. Answer the two questions below.

1. What caused the ice to increase in temperature between points A and B? Use ideas about energy to describe what occurs at the molecular level and how that relates to the temperature of the ice.

2. Below is a molecular-level drawing of water molecules at point A. Using your explanation from the previous question, construct a molecular-level drawing of these molecules at point B.



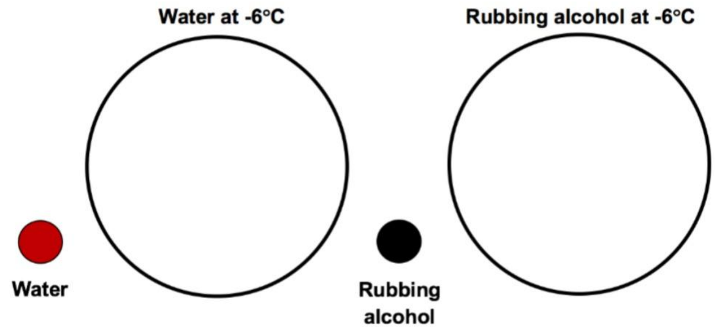
3. Based on the drawing of water molecules from the previous question, construct a molecular-level drawing of these molecules at point C.



4. Using the drawing you constructed in the previous question, explain why the temperature did not increase between points B and C. Focus on forces and energy in your explanation.

Kellie decided to try the experiment again, only this time using another substance to see if the new substance behaves the same as water. To do so, she poured rubbing alcohol into three cubes in the ice tray next to three cubes with water, put a thermometer on each cube and placed the tray in a freezer. After several hours, she took out the tray and noticed that, although both substances were at the same temperature (about -6 degrees Celsius), the rubbing alcohol did not freeze and remained liquid, while the water cubes were mostly frozen ice.

5. Kellie was curious why, even though the two substances were at the same temperature, the water was solid while the rubbing alcohol was still a liquid. She sought a molecular level explanation for the difference in properties between rubbing alcohol and water. To help her with this, let's construct some molecular-level drawings.



6. Using the drawings above, explain why, when Kellie took out the tray from the freezer, the water was still mostly solid but the rubbing alcohol was liquid. Focus your explanation on the relative strength of the electric forces between molecules.

[HS-PS3-2 Assessment - Evaporative Cooling]

Universal Supports	Targeted Supports
• Collaborate with students and draw a heat curve for water from its frozen to its gaseous state for the class. Lead discussion as students investigate the differences in the lengths and slopes of each part of the curve. • Students can draw a particulate diagram for each part of the curve in a graphic organizer. • Use a laminated heat curve for individualized instruction. Focus on one section. Have students explain what is happening on a macroscopic level on the selected section of the curve. Continue to a different part of the curve and explain the macroscopic observations. Have students explain what is happening on a molecular level. (Molecules are speeding up, slowing down, moving closer or further apart, etc.)	• Monitor progress and provide assistance as necessary. • Provide a partially completed graphic organizer

Common Misconceptions

- On a heat curve, a misconception is that boiling point temperature and condensation temperature are different. They are the same temperature as a substance undergoing vaporization or condensation.
- A common misconception is that changing from liquid to solid is an endothermic process. It is exothermic, and heat energy is released.

Culturally and Linguistically Responsive Instruction

	Guiding Questions and Connections
	- Use videos or articles related to ice and snow about inventors, athletes, and scientists that include the diversity of students in the classroom. - Invite students to share their experiences with ice and snow. Be aware that some students have less experience than others with ice or snow while others may have experienced ice fishing, ice skating, or ice hockey. - Keep in mind that not all students in the state have access to air conditioning or refrigeration. - Allow students to brainstorm how a change in temperature affects the exchange of energy.

Students who demonstrate understanding can:

HS-PS3-3. **Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [*Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*]

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 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**PS3.A: Definitions of Energy** • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. **ETS1.A: Defining and Delimiting an Engineering Problem** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary)*	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. - - - - - - - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering and Technology on Society and the Natural World** • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Connections to other DCIs in this grade-band:
HS.ESS3.A

Articulation of DCIs across grade-bands:
MS.PS3.A ; **MS.PS3.B** ; **MS.ESS2.A**

Common Core State Standards Connections:

ELA/Literacy -

WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS3-3)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS3-3)
MP.4	Model with mathematics. (HS-PS3-3)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-3)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-3)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-3)

Grade	*NGSS Discipline*
HS	**Physical Science**
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.* Video resources: [WIND TURBINES in NM]()

The Argonne Mesa Wind Facility near Santa Rosa is one of many in New Mexico. Luis Sánchez Saturno/The New Mexican file photo

The state of New Mexico is becoming more reliable on renewable energy sources. Wind farms are being developed throughout the state. Begin discussion and make a classroom chart of questions about energy and wind turbines. Discuss the purpose of the wind turbine. Explain how the turbine works to produce electricity. Discuss where the energy comes from to turn the blades, and how that motion produces electricity. Compare the actions of a wind turbine to the electricity produced by a hydroelectric dam such as Hoover Dam. This will expose students to renewable energy that is seldom seen in New Mexico.
Discuss the conversion of mechanical energy to electrical energy in both scenarios.

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.

Working with Wind

Students will design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Tryengineering.org is a website that is part of the Institute of Electrical and Electronics Engineers (IEEE) for teachers and students with classroom resources.

Students will work in teams to design, construct, and test a windmill that will turn and lift a load as specified in the procedures. There will be an energy conversion. All teams will present their windmills to the class. They will evaluate their windmill and refine it if necessary.

Working with Wind Energy

1. Define the objects in your system.
2. Construct a mathematical model for the efficiency of energy transfer.
3. Using the given information, calculate the efficiency.
4. Explain one way to modify the windmill to improve its efficiency. Use evidence and reasoning to support your claim.

Universal Supports	Targeted Supports
● Provide graphic organizers for students to organize their thoughts ○ Students will research the history of windmills and their uses and present their findings by creating a timeline. They must include changes over time as blade design and technology improved. Remind students of how energy is transferred. ● Before conducting small group activity, make sure that all students understand the expectations, instructions, and their role in the performance of the task. The teacher may check for understanding by asking questions regarding the expectations and how to complete the task. ○ Students can collaborate in groups with selected windmills as their research project and explain design flaws and improvements.	● Provide individualized instruction using a science notebook and providing a generalized schematic drawing of a windmill to review its parts and their functions. Students will discuss each part and its function. Remind students of how electricity is generated from the wind through the turbine and into the generator. ● Monitor student progress and provide assistance using multiple strategies.

Common Misconceptions

- A common misconception is that a machine can have an efficiency greater than 100%. Though not very much energy is lost to the surroundings in a mechanical device, friction and heat account for a loss of energy that will result in efficiency less than 100%.
- Windmills are not only used to generate electricity, but have been used in grain mills and as water pumps for centuries.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- How are or have windmills been used in different areas of the state?
- Provide examples of the use of windmills in different cultures and for different purposes.
- Watch the TED talk or read an excerpt from the book, The Boy Who Harnessed the Wind, by William Kamkwamba about how he built a windmill for his home in a village in Malawi using knowledge from a library and rudimentary scrap parts.
- Consider the familiar windmills that were in the book, Don Quixote, or the windmills of the Netherlands.
- Why were they important, and what were their purposes, and how does the conversion of energy exemplify itself in the examples?

Students who demonstrate understanding can:

HS-PS3-4. **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]

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 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.
- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Disciplinary Core Ideas

PS3.B: Conservation of Energy and Energy Transfer
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

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

Crosscutting Concepts

Systems and System Models
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Connections to other DCIs in this grade-band:
HS.ESS1.A ; HS.ESS2.A ; HS.ESS2.D

Articulation of DCIs across grade-bands:
MS.PS3.B

Common Core State Standards Connections:
ELA/Literacy -

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-PS3-4)*
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-4)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS3-4)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS3-4)
MP.4	Model with mathematics. *(HS-PS3-4)*

Grade	*NGSS Discipline*
HS	**Physical Science**
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.* On a very hot New Mexico summer day, it is important to hydrate. Many people enjoy cold beverages especially when they are working outside. Companies often provide coolers to keep bottled drinks cold. Of course, some coolers stay cold longer than others. Watch the video about the Yeti cooler to begin

conversation and questions about energy inputs and outputs and reduction of energy loss by using insulation.

- Video resource: YETI Cooler Insulation | What Makes YETI Coolers Better?
- Asking Questions Graphic Organizer

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.

Biodegradable Styrofoam

Around the country, cities and towns are starting to ban styrofoam. Polystyrene is a type of plastic manufactured from non-renewable fossil fuels and synthetic chemicals. It usually comes in two forms: *expanded polystyrene foam* (EPS), which is the stuff that's made into cups, plates, take-out food containers, and packing materials; and *solid polystyrene*, which gets turned into plastic forks, CD and DVD cases, and even smoke detector housings.

Styrofoam is how most of us generically refer to the EPS material, but it's actually a term trademarked by the Dow Chemical Company for extruded polystyrene that's used in thermal insulation and craft applications. Why are municipalities objecting to the use of Styrofoam? The ban of styrofoam stems from how it is produced and pollutes the air. Styrofoam is not biodegradable and can be easily broken up into small pieces and even minuscule pieces. The smaller styrofoam gets, the harder it is to clean up. Animals sometimes eat it. Turtles and fish seem to mistake Styrofoam for food, and that can kill them. Not only can they not digest it, but the foam could be full of poisons that it has absorbed from contaminants floating in the water. Estimates are that it takes from 500 years to 1 million years for styrofoam to break down and it can't be recycled.

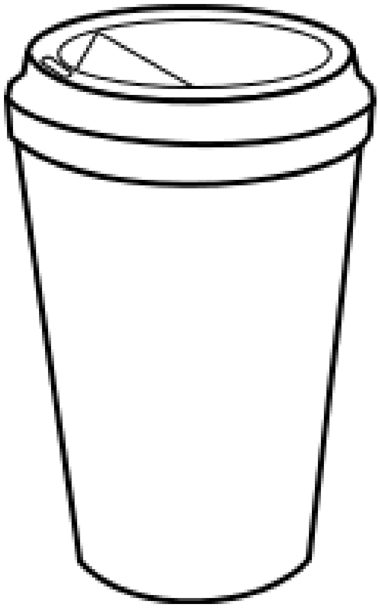
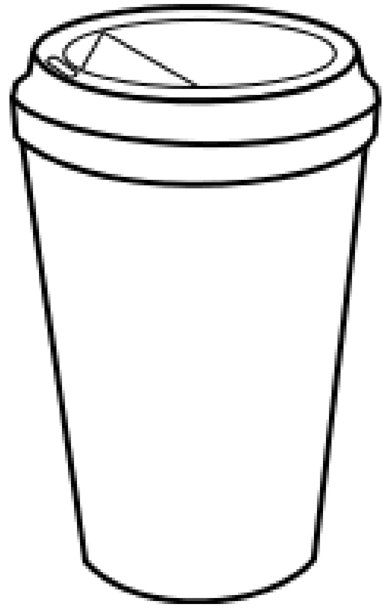
The science department is looking for a possible replacement for the styrofoam cups that have been traditionally used to conduct calorimetry experiments. Over the course of the calorimetry experiment, the traditional styrofoam cups have served as effective insulators from the surrounding environment so that the transfer of energy in the system can be investigated. Unfortunately, because of the repeated use of the styrofoam cups between different chemistry classes, the cups need to be replaced every year so they cannot be reused.

The environmental club has recommended that the department should use a biodegradable foam product from WinCup. The manufacturer claims that their Vio Biodegradable Cups are comparable replacements for regular styrofoam. The cups have been shown to biodegrade up to 92% in landfill-simulated environments in only four years. The biodegradability is due to the addition of additives to the EPS. Also, out of the products that the environmental club could find, it was the cheapest possible replacement.

TASK: In anticipation of a ban on non-recyclable EPS in our community, we need to determine whether the Vio biodegradable cup could be a viable alternative. You have to plan and conduct an investigation to provide evidence that the Vio biodegradable cup can serve as an effective insulator so that students can study the transfer of thermal energy between metal objects and water.

1. In the space below, construct a plan on how you will conduct an investigation to see how the Vio biodegradable EPS cups compare to traditional styrofoam cups as a system to study the thermal energy transfer between two objects. You can only use the materials provided by your teacher.
2. The distribution of energy changes in the calorimeter system over the course of the experiment. In the questions that follow, assume that the calorimeter is a closed system with the walls of the cup acting as the boundary to the surroundings.
    a. Demonstrate the movement between the components of the system in the model below. In your model, be sure to show particle movement in the metal object and water.

Before	After

3. At one point in the experiment, the energy will be uniformly distributed between the components of the calorimeter system.
    a. When in the experiment will you know that the energy is distributed uniformly? What evidence collected could you use to support your claim? Justify your response.
4. Construct a data table below to record the data used to determine the amount of thermal energy transferred by both objects. As you conduct the investigation, input the collected data in your data table.
5. Calculate the average amount of thermal energy lost or gained by either the water or the metal object. The biodegradable cup and the non-recyclable styrofoam cup used in your calorimetry experiments were not closed systems.
6. Using the evidence in the experiment and your calculations above, explain how you know that the two cups were not closed systems.
7. In the space below, draw a model that demonstrates how the two cups were not acting as closed systems. In the model, be sure to show the differences observed between the non-recyclable Styrofoam cup and biodegradable cup.

Non-recyclable Styrofoam cup	Biodegradable cup

8. What is your recommendation to the chemistry department about the cups to be used in future calorimetry experiments? Support your answer with evidence collected during the investigation and a discussion of the movement of energy.

[HS-PS3-4 Assessment - Biodegradable Styrofoam (NY)]

Universal Supports	Targeted Supports
• Create a graphic organizer for students to brainstorm different types of insulation. (homes, winter clothing, refrigerators, ovens, containers, etc.) • Have students do a gallery walk to present their findings on a poster for the class with an analysis for each kind of insulation based on materials used, effectiveness in maintaining a desired temperature, and any environmental impacts. Students must be able to explain the transfer of energy that occurs and how the insulator affects the transfer of energy. • Before conducting small group activity, make sure that all students understand the expectations, instructions, and their role in the performance of the task. The teacher may check for understanding by asking questions regarding the expectations and how to complete the task.	• Provide examples of insulated objects such as a winter coat, coffee cup, ice chest. Ask struggling students what the purpose of each object should be and what would happen if the materials were changed. • Monitor progress and provide assistance using questioning techniques.

Common Misconceptions

- A common conceptual misconception is that heat energy is reduced when a hot object comes in contact with a cold object. There is not a reduction in energy, but a transfer of energy instead.
- Some students might think that all forms of insulation are the same.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Open discussion by asking how food was kept cold before electric refrigerators became common in today's society?
- Consider energy exchange and how insulation can affect food preservation, clothing, or containers used in other cultures.
- Ask for student experiences with hot and cold and how insulation plays a role in their experiences.
- Ask students about styrofoam cups as litter in the areas where they live. Do they pose a threat to their environments?
- Be mindful of responsiveness to opinions about litter and littering.
- Why or why is it not important to pick up trash in our neighborhoods?

Students who demonstrate understanding can:

HS-PS3-5. **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [*Assessment Boundary: Assessment is limited to systems containing two objects.*]

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 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS3.C: Relationship Between Energy and Forces** • When two objects interacting through a field change relative position, the energy stored in the field is changed.	**Cause and Effect** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Connections to other DCIs in this grade-band:
HS.PS2.B

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

Common Core State Standards Connections:
ELA/Literacy -

WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS3-5)*
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-5)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS3-5)*
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-5)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS3-5)
MP.4	Model with mathematics. (HS-PS3-5)

Grade	*NGSS Discipline*
HS	**Physical Science**
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.* Obtain paper dots from a hole punch. Hold a plastic ruler above the paper dots. Record any observations. Rub the plastic ruler with a piece of wool. Hold the ruler above the paper dots. ● Discuss the effect of the ruler on the paper dots. ● Why is there an attraction only after rubbing the ruler with wool? ● Discuss the normal force and the force of gravity acting on the paper dots before the charged ruler is held above them and the electrostatic force that is stronger than gravity acting on the paper dots when the charged ruler is nearby. ● What other materials might exhibit similar behavior?

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.

HS-PS3-5 Assessment - Space Station Transport System

Background:
A team of engineers are considering using electric fields to move objects to different locations on the International Space Station. The plan is to have metal plates located on the outside of the station that could be charged to attract and repel charged transport pods.

The team needs an accurate model of objects interacting through electric fields so they are using a well-known phenomenon called the electric ping-pong.

Your Task:
Use evidence from their investigation to build an accurate model of forces and energy in objects interacting through electric fields and sketch a preliminary design for this transport system.

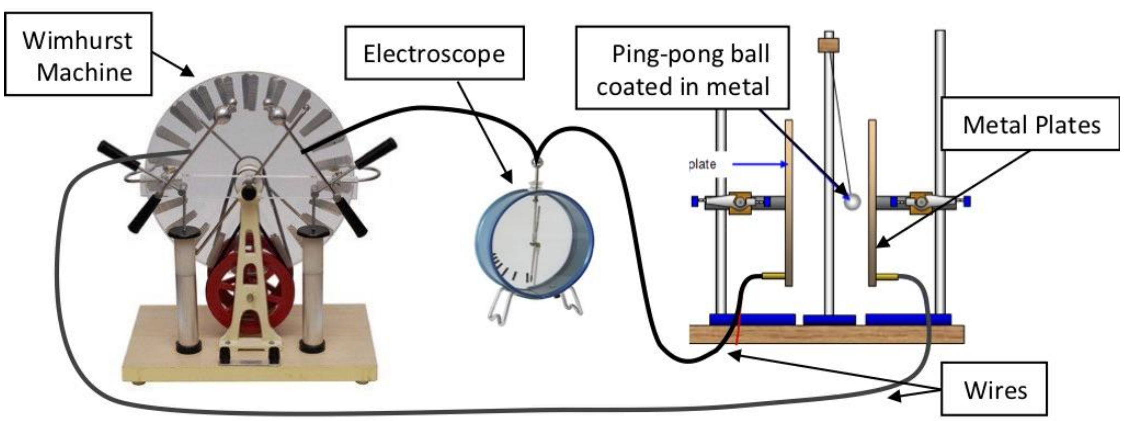


Figure 1: Electric ping pong apparatus

The Wimhurst Machine generates a static electric charge. Connected wires allow opposite charges to build up between the two metal plates. A ping-pong ball coated in metal is suspended between the plates. It loses and gains a small electric charge during collisions. An electroscope, connected to one side of the Wimhurst machine, measures the amount of charge created by the machine and lost by the ping-pong apparatus.

Watch a YouTube video of the investigation. You will analyze the data on the following three pages.

Video Thumbnails

Real Time	4x speed with electric	1/8x speed motion tracked

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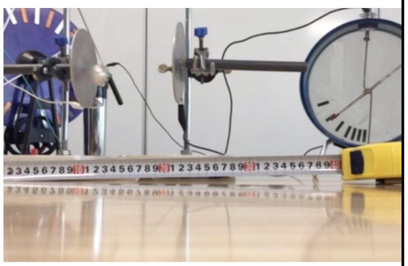
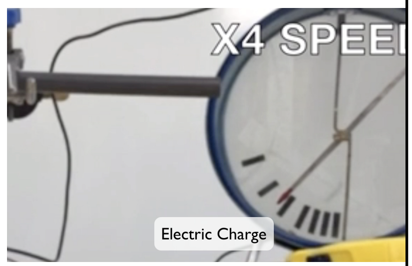
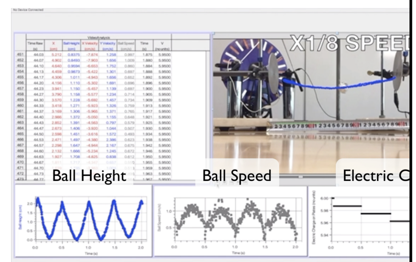
<td></td>
<td></td>
<td></td>
</tr>
</table>

Data Sets:

The resulting x and y positions (the y-position is shown in Figure 2) of the ball were measured, and from this the speed was calculated at each instant (Figure 3). While the apparatus was operating, the electroscope measured changes in electric charge on the metal plates as shown in Figure 4.

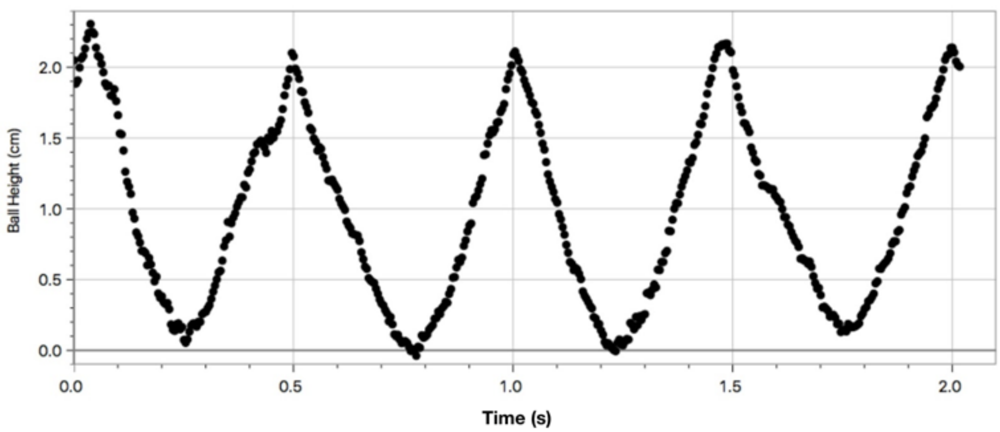


Figure 2: Height of ping-pong ball while bouncing between plates

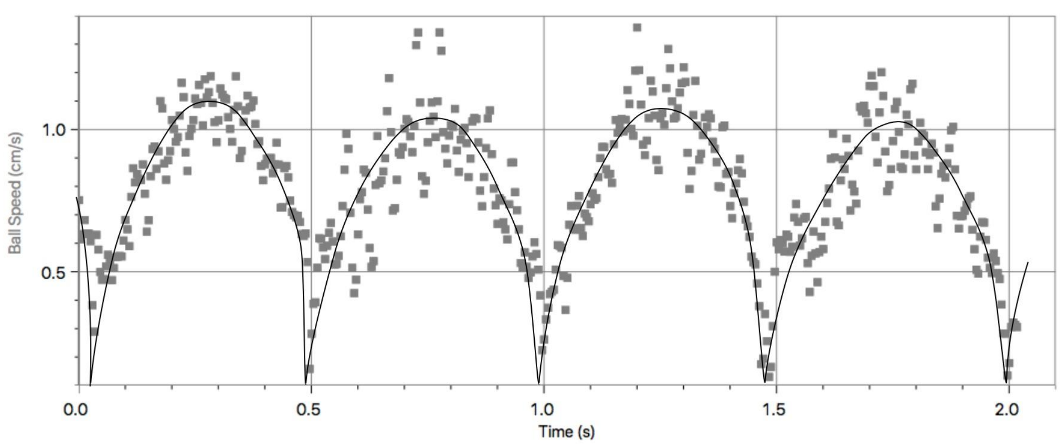


Figure 3: Speed of ping-pong ball while bouncing between plates

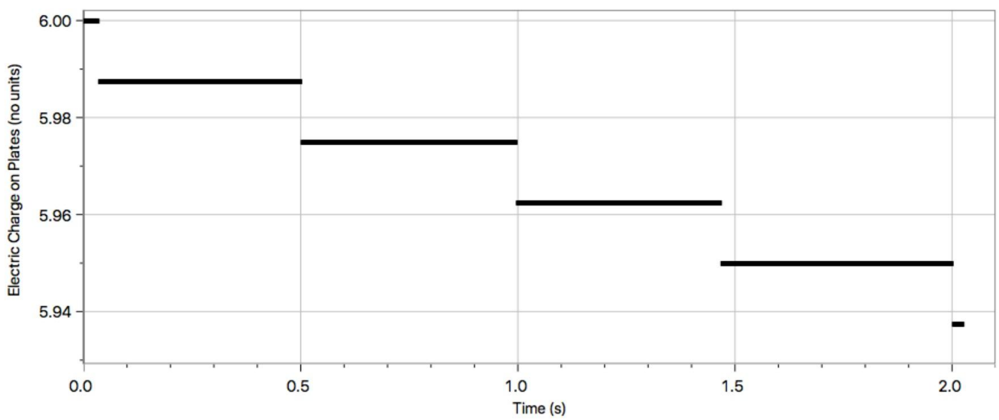


Figure 4: Difference of electric charge between the two metal plates

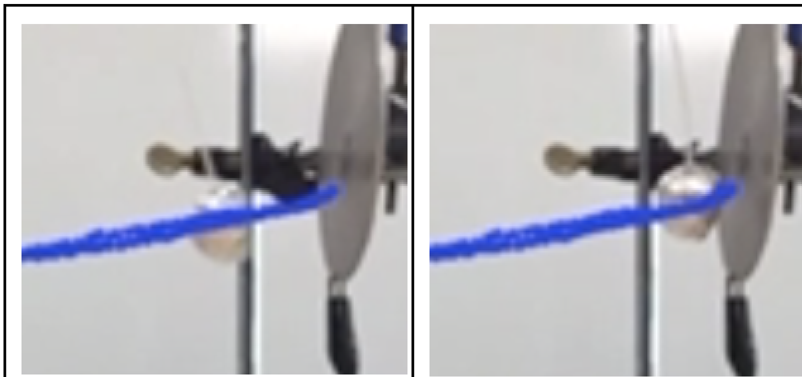
Analysis:

1. Look at the figures on the previous page and use them to complete the questions on the table below.

Figures	**What patterns do you see?** Be sure to use data from the figure to support your answer.
Figure 1: Height of ping-pong ball	
Figure 2: Speed of ping-pong ball	
Figure 3: Electric charge across plates	

Interpretation:

Time = 1.4 s	**Time = 1.5 s**



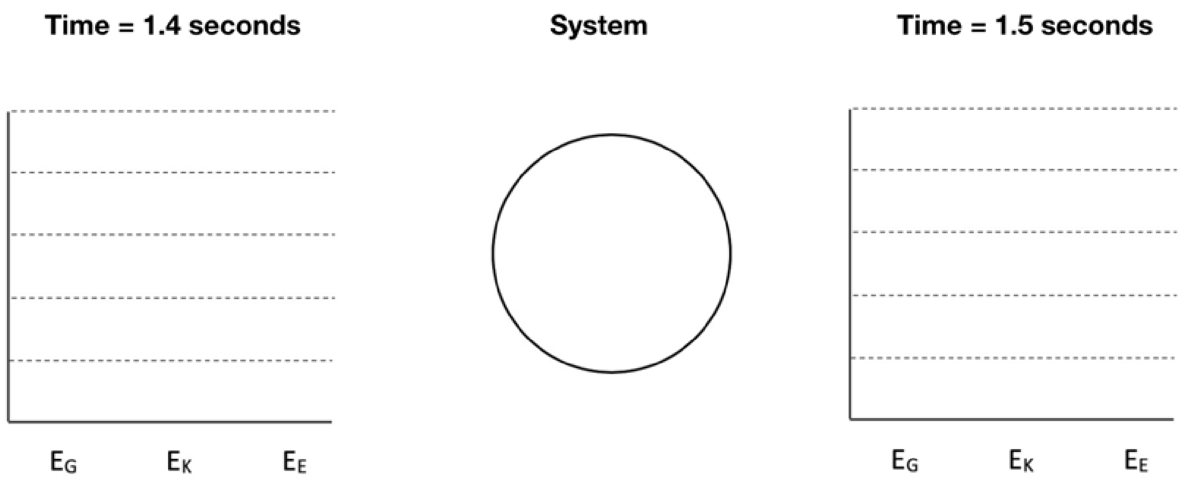
1. Draw a free-body diagram to show the relative magnitude and direction of all forces acting on the ping-pong ball at **time = 1.4 s** and **time = 1.5 s**. Ignore air resistance as a force.

Time = 1.4 s	Time = 1.5 s

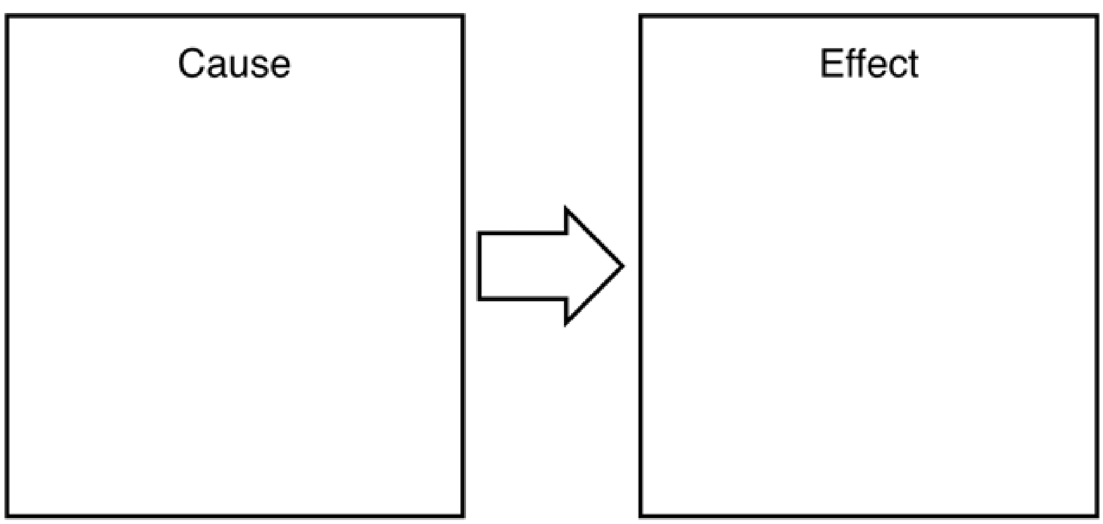
2. Draw a model of the ping-pong ball and plates at 1.4 and 1.5 seconds. Your model should include the **charges**, **electric fields,** and **velocities** of the interacting objects.

Time = 1.4 s	Time = 1.5 s

3. Model the ping-pong ball's **energy transfer** between 1.4 and 1.5 seconds in the diagram below. Assume the system is the ping-pong ball. Show and label energy leaving or entering the system.
   (E_G for Gravitational Energy, E_K for Kinetic Energy and, E_E for Electric Potential Energy)



4. Use the graphic organizer below to describe the cause and effect relationships between the forces produced by the electric field and the change of energy of the objects in the system.



5. Based on your understanding of energy transfer in the phenomenon, sketch a preliminary design for the transport pods proposed for the International Space Station. Include an energy source and account for energy loss in your design.

Universal Supports	Targeted Supports
• Have students write in graphic organizers how they have experienced static electricity and how it can be generated and draw a diagram about static electricity. . • Use a model of the charged particles on a diagram and how they can attract or repel each other. How could the attraction and repulsion forces of static electricity be used in a real application? • Show students a video or a model of the International Space Station (ISS) and the pods that are used for transport that need to be docked or moved to different locations on the ISS. Have students propose a different way to dock pods on the ISS that uses static electricity safely.	• Provide partially completed graphic organizers • Model static electricity using the phenomenon presented above. • Monitor progress and provide assistance as necessary.

Common Misconceptions

- Students might believe that friction between objects is necessary for static charges. What is actually required are two different insulators that come into contact and then separate.
- Students may think that the rubber tires on a car protect them during a lightning strike when it is actually the metal frame of the car, a conductor, that distributes like charges which repel the like charges of the lightning.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Ask for experiences with static electricity and make a chart of culturally different experiences.
- Show videos or present articles about static electricity that are representative of all cultures and languages.
- Materials used to generate static electricity may not be readily available to all students or may represent a sensitive issue. For example, some students may object to the use of rabbit fur often used when generating static electricity.
- How can an interaction with static electricity be harmful in your home?

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.