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New Mexico STEM Ready! Science Standards Implementation Guide

Overview

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

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

The standards

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

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

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

The connections box identifies connections to other disciplinary core ideas at this grade level that are relevant to the standard, identifies the articulation of disciplinary core ideas across grade levels, and identifies connections to the *Common Core State Standards (CCSS)* in mathematics and in English language arts and literacy that align to this standard. The connections box helps support instruction and development of instructional materials.

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

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.

<u>How:</u> 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

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[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-PS2-1. **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.** [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]

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

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- Theories and laws provide explanations in science.
- Laws are statements or descriptions of the relationships among observable phenomena.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects.

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-level:
HS.PS3.C ; HS.ESS1.A ; HS.ESS1.C ; H.ESS2.C

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

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-PS2-1)*
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS2-1)*

Mathematics -

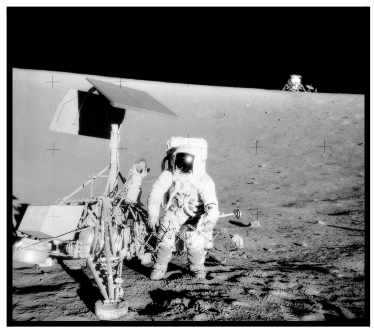
MP.2	Reason abstractly and quantitatively. (HS-PS2-1)
MP.4	Model with mathematics. (HS-PS2-1)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-1)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1)
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1)
HSA.CED.A.1	Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1)
HSA.CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-PS2-1)*
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS2-1)*
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. *(HS-PS2-1)*
HSS-IS.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots). *(HS-PS2-1)*

Grade	NGSS Discipline
HS	Physical Science 2.1

PS2-1

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.



Do heavier objects fall faster?

1. Which will hit the ground first? As students carry out activities, they collect data that will be mathematically analyzed and used to answer the prompt.
    a. Drop a heavy ball vs. a light ball (basketball vs. tennis ball; bowling ball vs. basketball, etc.) at various heights
    b. Drop differently shaped objects (flat paper vs. crumpled paper) at various heights
2. After completing the activities, students will watch videos of objects being dropped in a vacuum chamber (videos available on line).
3. As a thought problem, have the students recall a time when they pushed a shopping cart (or pulled a wagon) and how their pushing changed as items were added to the cart. Relate the ball drop and cart scenarios together through a discussion of F = ma.

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.

Newton's 2nd Law Assessment

1. Two spheres are dropped from an initial height in an environment of negligible air resistance. Sphere A has a mass of 20.0 g and sphere B has a mass of 100.0 g. Video tracking software is used to determine the position of the spheres as a function of time.

   Prove that the acceleration of both objects are the same. Your answer must include:
   - A definition of the system being studied.
   - One or more graphs that organize the data.
   - Evidence from the graph(s) in support of the acceleration of both objects being the same.
   - One or more free body diagrams.
   - Use of the free body diagram(s) in support of the acceleration of both objects being the same.

2. A second trial is conducted using the same two spheres. Below are the velocity vs. time graphs for spHypothesize what was different about trials 1 and 2 that caused different results.

   Hypothesize what was different about trials 1 and 2 that caused different results. Your answer must include:
   - A description of the acceleration of spheres A and B.
   - A cause and effect explanation of the difference between the motion of spheres A and B in trial
   - A hypothesis explaining what was different about trials 1 and 2 causing different results in the form of CLAIM, EVIDENCE, REASONING.
     - Engaging in Argument from Evidence Graphic Organizer
   - Hypotheses for what may have caused irregularities in data for sphere A at t = 1.07 s and for sphere B at 2.20 s.

Universal Supports	Targeted Supports

• Utilize anchor charts to model graph components: axes labels, data intervals, type of graph (line, bar)
• Create anchor charts to review of Newton's 2nd law, give descriptive explanation of the concept behind the math
• Free-body diagram gallery walk for students
  ○ Have students pick examples of objects in motion or at rest and draw the free-body diagrams showing all forces involved
  ○ Provide Post-its for students to ask questions or provide feedback during the gallery walk
• Conduct labs/activities showing constant velocity and acceleration of an object (battery powered cart, ball of differing masses on ramp), collect data on time, position, velocity and calculate acceleration. Students decide
	• Check for understanding, find major misconceptions and give directed instruction to those who need it
	• Monitor and assist students with any observed mathematical and computational errors

how to collect, organize and analyze data from activity
- Utilize Read, Talk, Write strategy
  - Give student examples of motion graphs and have them explain what the graph represents; this could be done in words or in a physical (movement) way

Common Misconceptions

- Heavier objects fall faster than lighter objects (preconceived notion)
- An object at rest has no forces acting on it (conceptual)
- Students think that acceleration is only deals with a change is speed (conceptual)
- If an object has zero acceleration, it must be at rest
- Energy and force are the same thing
- The forces exerted on an object are unbalanced when the object moves with constant velocity.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- What type of laws are you familiar with in your own life (at home and in society)?
- What are the differences between a natural law and a governmental law?
- What happens when you “break” a natural law compared to breaking a governmental law?
- How does science identify and decide what is a natural law?
- Include research on historical and biographical data for culturally connected individuals who have contributed to the development of this topic.
- Ensure everyone understands the role they should partake in a task (linguistic)
- Ensure visuals/articles/videos are representative of all cultural groups
- Students set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing.

Students who demonstrate understanding can:

HS-PS2-2. **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] *[Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]*

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
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. • Use mathematical representations of phenomena to describe explanations.	**PS2.A: Forces and Motion** • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Connections to other DCIs in this grade-level:
HS.ESS1.A ; **HS.ESS1.C**

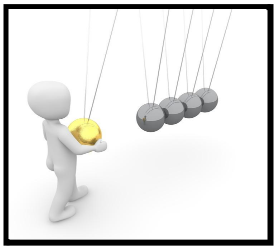
Articulation of DCIs across grade-bands:
MS.PS2.A ; **MS.PS3.C**

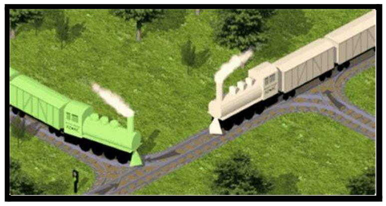
Common Core State Standards Connections:
Mathematics -

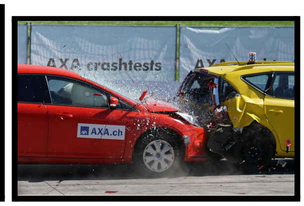
MP.2	Reason abstractly and quantitatively. (HS-PS2-2)
MP.4	Model with mathematics. (HS-PS2-2)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-2)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-2)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-2)
HSA.CED.A.1	Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-2)
HSA.CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-PS2-2)*
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS2-2)*

Grade	*NGSS Discipline*
HS	**Physical Science 2.2**
PS2-2	**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.*

Everyday phenomena:







1. Students will be shown the concept of momentum and its conservation through videos and class demonstrations, appropriate and various examples of colliding objects with the same masses, Newton's cradle, pool/billiard balls, and then with different masses, bowling ball vs. pins, car crashes (with airbags), sports activities, etc.
    - Video Resources
        - Newton's Cradle - Incredible Science
        - Amazing Billiards in Super Slow Motion
        - 2016 Toyota Hilux - Crash Test
        - Bowling Strike in SLOW MOTION!

2. After viewing the examples, discuss the concept and calculation of momentum, impulse and the conservation of momentum in a closed system (sometimes you're the windshield, sometimes you're the bug).

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.

Formative assessment for mathematical problem solving involving conservation of momentum for this unit should occur during class as concepts are discussed.

Group Activity: Students will be given data from a rear-end car crash, and through the use of the law of conservation of momentum determine if the cars were traveling the speed limit. Data for cars #1 and #2 will include mass, initial velocity (for car #2 only), final velocity, and speed limit. Car #2 is stopped at a stop sign and car #1 fails to stop and rear ends #2.

- Was car #1 speeding? In groups students must make a claim and support it with mathematical evidence and present their findings to the entire class.
    - Using Mathematical and Computational Thinking Graphic Organizer

Momentum and Its Conservation Assessment (extra practice if needed)

Conservation of Momentum and Impulse Assessment

1. Which has more momentum, a fully loaded semi trailer sitting at the loading dock or a falling raindrop? Explain your answer.

2. A 0.174-kg softball is pitched horizontally at 26.0 m/s. The ball moves in the opposite direction at 38.0 m/s after it is hit by the bat.

   a. Draw arrows showing the ball's momentum before and after the bat hits it.
   b. What is the change in momentum of the ball?
   c. What is the impulse delivered by the bat?
   d. If the bat and softball are in contact for 0.80 ms, what is the average force that the bat exerts on the ball?

3. Two freight cars, each with a mass of 3.0105 kg, collide and stick together. One was initially moving at 2.2 m/s, and the other was at rest. What is their final speed?

4. A 0.105-kg hockey puck moving at 24 m/s is caught and held by a 75-kg goalie at rest. With what speed does the goalie slide on the ice?

5. A 35.0-g bullet strikes a 5.0-kg stationary piece of lumber and embeds itself in the wood. The piece of lumber and bullet fly off together at 8.6 m/s. What was the original speed of the bullet?

6. A 35.0-g bullet moving at 475 m/s strikes a 2.5-kg bag of flour that is on ice, at rest. The bullet passes through the bag, as shown below, and exits it at 275 m/s. How fast is the bag moving when the bullet exits?

7. The bullet in the previous problem strikes a 2.5-kg steel ball that is at rest. The bullet bounces backward after its collision at a speed of 5.0 m/s. How fast is the ball moving when the bullet bounces backward?

8. A 95-kg fullback, running at 8.2 m/s, collides in midair with a 128-kg defensive tackle moving in the opposite direction. Both players end up with zero speed.

   a. Identify the "before" and "after" situations and draw a diagram of both.
   b. What was the fullback's momentum before the collision?
   c. What was the change in the fullback's momentum?
   d. What was the change in the defensive tackle's momentum?
   e. What was the defensive tackle's original momentum?
   f. How fast was the defensive tackle moving originally?

Universal Supports	Targeted Supports

• Discuss the equation for momentum as a class, defining each variable and the units of measurement. • As a refresher for algebra skills, have the students isolate each variable in the equation and identify its relationship to the other variables. • Review the units used to measure momentum, have students practice conversions within the metric system. • As a class, work out momentum and conservation of momentum problems. This could be done, checked immediately via electronic response, or hand written paper response. The teacher can check for correctness and give feedback for clarification.	• Monitor and assist students with any observed mathematical and computational errors.

Common Misconceptions

- Impulse equals momentum (rather than change in momentum) (conceptual)
- Students think that momentum is a force (conceptual)
- Things such as high-speed bullets contain force
- Impact and impulse are the same
- Momentum is conserved only when collisions are perfectly elastic

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Discussion of automobile accidents and ammunition (bullets) may be a trigger point for some people.
- Allow students to voluntarily share experiences they have had where the principle of momentum conservation was evident.
- Include research on historical and biographical data for culturally connected individuals who have contributed to the development of this topic.
- Ensure everyone understands the role they should partake in a task (linguistic)
- Ensure visuals/articles/videos are representative of all cultural groups
- Students set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing.

Students who demonstrate understanding can:

HS-PS2-3. **Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*** [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]

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. • Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.	**PS2.A: Forces and Motion** • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. **ETS1.A: Defining and Delimiting an Engineering Problem** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary)* **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary)*	**Cause and Effect** • Systems can be designed to cause a desired effect.

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

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

Common Core State Standards Connections:
ELA/Literacy -

WHST.11-12.7 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-PS2-3)

Grade	*NGSS Discipline*
HS	**Physical Science 2.3**
PS2-3	**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.*

How have automobile safety features improved over time and what does physics have to do with it? Or, how can an explosion save your life? Class discussion will focus on student's experiences with car safety features (possible trigger point if students have experienced an auto accident). Air bags will be the focus, but all safety items can be explored from a physics concept standpoint. As different items are explored, the topics of force and impulse will be discussed for each.

1. Automobile safety features: airbags, impact absorbing car body materials, cameras, radar
   Extra topics if needed:
2. Sports equipment: helmets, body padding, tumbling mats
3. Shipping/packaging materials used to cushion objects
4. Equipment to land spacecraft on Earth, parachutes
5. Landing surface type (land or water) for space vehicles

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.

Airbag Effectiveness (Teacher)

Airbag Effectiveness Student Task (Student)

Airbags are engineered to be as protective as possible during car crashes. Because of this, the process of testing airbags in car crash simulations is a robust process, and precise data must be collected in order to produce the optimal design. One way to assess the effectiveness of an airbag in a simulated car crash is to collect force measurements over time. When a crash test dummy collides with the airbag, the force applied to the dummy is measured and recorded by a computer after each--usually very short--time interval during the simulation. Researchers recorded the force on a dummy in a series of car crashes. In each of the crashes, the car was going 40 mph and crashed into a concrete wall. Researchers recorded the forces over a short period of time (0.065 s) for three different airbag designs as well as one crash without airbags. Your task is to analyze the data from the trials listed below. Use this analysis to construct an argument about which airbag design provides the most protection, citing patterns from the data as evidence for your claim.

	Force (kilonewtons)			
Time (sec)	Design 1	Design 2	Design 3	No Airbag
0	0.00	0.00	0.00	0.00
0.005	0.00	7.38	0.00	0.00
0.010	0.00	46.18	8.65	2.30
0.015	7.63	84.08	33.45	5.72
0.020	56.03	91.87	83.88	232.54
0.025	101.84	90.08	147.50	222.68
0.030	126.81	81.03	111.23	67.44
0.035	114.13	54.13	77.43	16.23
0.040	64.84	36.96	36.55	4.17
0.045	38.15	29.96	22.76	0.00
0.050	17.78	18.20	9.43	0.00
0.055	5.04	10.87	0.00	0.00
0.060	0.00	4.31	0.00	0.00
0.065	0.00	0.00	0.00	0.00

Students should complete a graph of the data above.

1. Provide an analysis of the data provided to you. You may use computation, a verbal description/comparison of the data, graphs or some other visual representation in your analysis. Be sure to state any patterns you determine to be true from the data.
2. How does an airbag provide protection to a passenger in a crash?
3. Construct a written argument for which airbag design provides the most protection to a passenger. Support your claim with evidence and reasoning based on your analysis from Question 1 and your understanding of how an airbag provides protection to a passenger.

Universal Supports	Targeted Supports
• Through videos, photographs, and text resources, show images of the products and materials that are designed to operate as collision safety devices. Explain the function and properties of the devices that are involved in use. • A history of the development and evolution of safety devices in all areas of life could be researched by the students (first air bags, restraints). Students could focus on one item and trace its engineering, refinement and implementation of its current form.	• Help students develop effective research questions to gather information when using online resources.

Common Misconceptions

- Impact and impulse are the same (conceptual)
- Airbags work by cushioning the collision (rather than the extending the time of the collision)

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Discussion of automobile accidents may be a trigger point for some people.
- What safety features are standard equipment in today's cars?
- Is it possible to make cars even more safe?
- Include research on historical and biographical data for culturally connected individuals who have contributed to the development of this topic.
- Ensure visuals/articles/videos are representative of all cultural groups
- Students set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing.
- Students set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing.

Students who demonstrate understanding can:

HS-PS2-4. **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with 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
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. • Use mathematical representations of phenomena to describe explanations. - - - - - - - - - - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena.	**PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-level:
HS.PS3.A ; ***HS.ESS1.A*** ; ***HS.ESS1.B*** ; ***HS.ESS1.C*** ; ***HS.ESS2.C*** ; ***HS.ESS3.A***

Articulation of DCIs across grade-bands:
MS.PS2.B ; ***MS.ESS1.B***

Common Core State Standards Connections:
Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS2-4)
MP.4	Model with mathematics. (HS-PS2-4)
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-PS2-4)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-4)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-4)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-4)
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-4)

Grade	*NGSS Discipline*
HS	**Physical Science 2.4**
PS2-4	**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.

Which is the stronger force: gravity or static cling?

If you've ever seen photos of astronauts on the moon or videos of them in their spacesuits, you may have seen what looks like slow-motion frolicking across the moon's surface. This isn't a glitch in the film or a trick of the light - on the moon, gravity is significantly less strong than it is on earth, resulting in the tall jumping motions you can see in the pictures. Every planet, moon, asteroid and meteor has a different gravitational pull. On the moon, you're actually much lighter than you are on earth, but what would your weight be on other planets like Mars, Jupiter, or even Pluto?

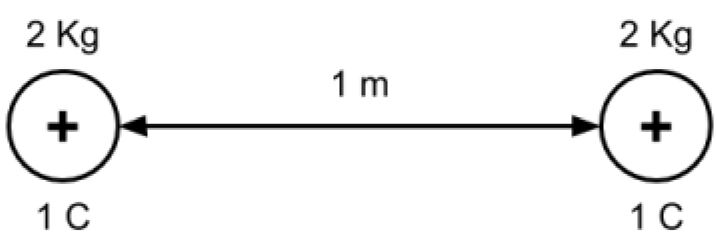
1. Students should calculate an object's weight on different planets, showing different gravitational forces by planet, and develop an explanation why different planets have different gravitational force. For another example, discuss the occurrence of tides on Earth.

2. To demonstrate electrostatic force, suspend two inflated balloons on strings, rub and charge the balloons then observe the attractive/repulsive forces created. You can also charge other objects and observe electrostatic forces. Students should propose hypotheses of why the charge exists and what will make it go away.

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.

You have two charged masses, as shown below, that are allowed to move freely without friction.



1. Using your knowledge of physics, predict and describe the motion of the two masses. In your description use both written and mathematical expressions to support your prediction.

2. Describe a situation in which two charged masses would be in equilibrium. Be sure to include your mathematical evidence to support the claim your system is in equilibrium.

Universal Supports	Targeted Supports
• Connectivity and access to technological resources must be verified and any issues solved before assigning computer-based tasks. • As students make calculations with provided data sets and formulas, unit review, scientific notation and equation manipulation will be monitored by the teacher and support given to students who need it. • Review of the experimental design process, highlighting key characteristics of effective and efficient procedures to use.	• Monitor and assist students with any observed mathematical and computational errors.

Common Misconceptions

- Students think that only large objects exert gravitational force (conceptual)
- mass and weight are the same thing (preconceived notion)
- students think that gravity is a stronger force than the electrostatic force between two particles
- Gravitational forces only apply to objects near the surface of a planet, not between planets.
- In a two-object system, the more massive object (or object with the greater charge) exerts a greater force on the other object

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- What do you know about the orbits of the planets in our solar system?
- Identify phenomena that are interesting and accessible to a range of students, emphasizing research done by NM scientists/engineers/researchers from different ethnic (etc.) backgrounds.
- Include research on historical and biographical data for culturally connected individuals who have contributed to the development of this topic.
- Students set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing.
- Ensure everyone understands the role they should partake in a task (linguistic)
- Ensure visuals/articles/videos are representative of all cultural groups

Students who demonstrate understanding can:

HS-PS2-5. **Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** [*Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.*]

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
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.	**PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. **PS3.A: Definitions of Energy** • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. *(secondary)*	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-level:
HS.PS3.A ; ***HS.PS4.B*** ; ***HS.ESS2.A*** ; ***HS.ESS3.A***

Articulation of DCIs across grade-bands:
MS.PS1.A ; ***MS.PS2.B*** ; ***MS.ESS1.B***

Common Core State Standards Connections:

ELA/Literacy -

WHST.11-12.7 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-PS2-5)

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-PS2-5)*

WHST.11-12.9 Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS2-5)*

Mathematics -

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-PS2-5)*

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-5)*

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS2-5)*

Grade	*NGSS Discipline*
HS	**Physical Science 2.5**
PS2-5	**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.

Investigative phenomena:
What makes magnets weaker and stronger? Why makes some magnets so strong they can erase data from credit cards and computers, but some so weak they barely stick to the refrigerator if you put a postcard between them? How is an electromagnet at the scrap yard able to pick up an entire car?

1. Students will be shown a simple electromagnet (teacher demonstration or video). The components of the device will be discussed and their function explained. The concept of electromagnetic induction will be explained.

2. Other examples of devices using electromagnetic induction can be discussed:
    a. Metal detectors
    b. Traffic signal sensors under the road surface
    c. Magnetic card readers

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.

An effective activity/assessment is the use of a virtual, computer-based lab experience. Students will become familiar with virtual lab set up and function, then design their own research questions, collect data, and analyze results.

PhET Lab Faraday's Law (Introductory simulation to Faraday's Law)

PhET Faraday's Electromagnetic Lab (Simulation to be used in assessment)

Assessment: Investigating the Faraday Flashlight

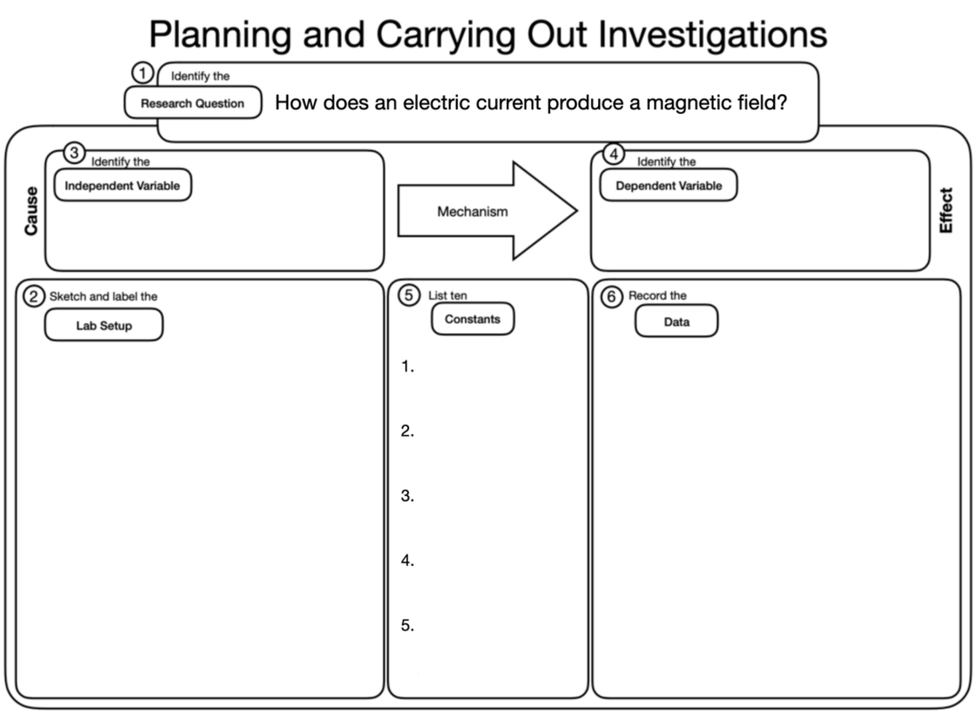
Investigating the Faraday Flashlight

The Faraday Flashlight is a mechanically powered flashlight. The flashlight contains a powerful neodymium magnet that moves back and forth between a coil of copper wire. Energy is generated and stored in a supercapacitor. Shaking the flashlight back and forth for 30 seconds will provide about 5 minutes of light. (image)

In this assessment you will be using Faraday's Electromagnetic Lab (a PhET Simulation) to **investigate Faraday Flashlight and improve its design**. You will need to answer the following two questions in your investigation:

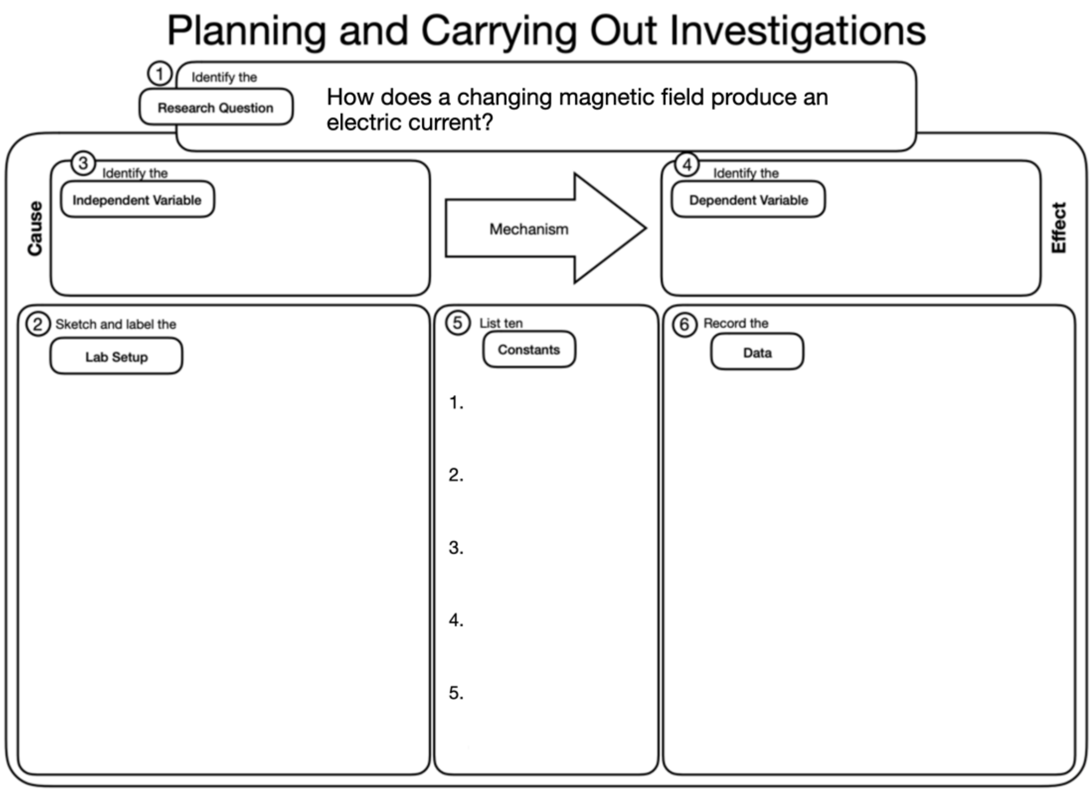
- How does an electric current produce a magnetic field?
- Use the following graphic organizer to identify the cause and effect you will be investigating:

1. How does a changing magnetic field produce an electric current?
2. What phenomenon will you be investigating? What is the purpose of this investigation?
3. Use the following graphic organizer to plan and then investigate the following question using Faraday's Electromagnetic Lab (a PhET Simulation).



4. How would you refine the design of your investigation to improve the accuracy and precision of the data that was collected?

5. Use the following graphic organizer to plan and then investigate the following question using Faraday's Electromagnetic Lab (a PhET Simulation).



6. Based on the results of your investigations, draw and explain a plan for an improved Faraday Flashlight in the space below:

Universal Supports	Targeted Supports
• Connectivity and access to technological resources must be verified and any issues solved before assigning computer-based tasks. • The interactive simulation will be projected and previewed as a class introduction to using the features of the simulation set-up. • Experimental design and hypothesis making will be reviewed and examples given to help students develop strategies to complete this task.	• Students experiencing problems can be helped one-on-one as issues arise.

Common Misconceptions

- Static magnetic fields produce electric currents.
- Generating electricity is a complicated process
- Motors and generators are different from each other
- Power companies deliver electrons, rather than energy, from a power plant to consumers

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Identify ways you have used electricity today.
- How would your household deal with a power outage?
- Include research on historical and biographical data for culturally connected individuals who have contributed to the development of this topic.
- Students set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing.
- Ensure everyone understands the role they should partake in a task (linguistic)
- Ensure visuals/articles/videos are representative of all cultural groups

Students who demonstrate understanding can:

HS-PS2-6. **Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [*Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.*]

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
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**PS2.B: Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

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

Articulation of DCIs across grade-bands:
MS.PS1.A ; MS.PS2.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-PS2-6)*

WHST.11-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS2-6)*

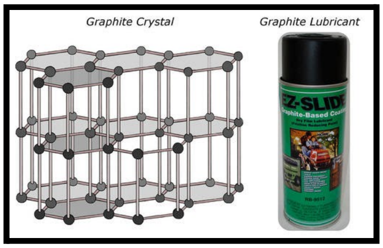
Mathematics -

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-PS2-6)*

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-6)*

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS2-6)*

Grade	NGSS Discipline
HS	**Physical Science 2.6**
PS2-6	**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.* **Everyday phenomena:**



1. Show examples of materials whose function directly stems from the microscopic properties of the material itself, i.e. synthetic fibers (Kevlar), crystalline forms of carbon (graphene, graphite, diamond), photovoltaic cells.

2. Other examples:
   - Electrical wires as an example of a metallic structure
   - Flexible but durable materials that are used for long chained molecules
   - Pharmaceuticals that are designed to interact with specific receptors

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.

This assessment provides text information about the different types of carbon-based materials. Students will answer text-based questions and use their knowledge of how molecular structure is important in the functioning of materials.

Graphene Article
Original article link: Graphene: The Next Wonder Material?
Web Source: The American Chemical Society

Directions: Read the article, "Graphene: The Next Wonder Material?" then answer the following questions.

1. Graphite is one of several forms of carbon. How can a single element exist in different forms?
2. How do the properties of diamond differ from the properties of graphite?
3. Why do graphite's properties make it useful for pencil "leads"?
4. What property of graphene may allow it to make computers run faster?
5. Identify two ways that the use of graphene in cell phone components will change the characteristics of the phone.

Universal Supports	Targeted Supports
• Review and discussion of reading nonfiction texts for information will be conducted before the task is assigned. Exemplar examples will be discussed, pointing out methods to effectively answer assigned questions.	• Teacher guided help during peer review occurs in small groups.

	• Chunk out tasks for creating nonfiction data summarization and reporting. • First draft review and editing will be used to provide students with guidance and help them refine their technical writing skills.	

Common Misconceptions

- Confusion of the terms intramolecular and intermolecular

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Identify the different types of materials that are used in everyday items.
- Identify man-made items vs. natural items in your household.
- What are similarities and differences between man-made and natural materials?
- Identify the microscopic features of materials that can lead to macroscopic properties.
- Are there materials in your daily experience that you would like to change or improve?
- Include research on historical and biographical data for culturally connected individuals who have contributed to the development of this topic.
- Ensure everyone understands the role they should partake in a task (linguistic)
- Ensure visuals/articles/videos are representative of all cultural groups
- Students set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing.

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.

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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.