Public Education Department

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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.

[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

[3] Penuel, W. R., Bell, P., Neill, T., Morrison, D., & Tesoriero, G. (2018). *Selecting Anchoring Phenomena for Equitable 3D Teaching*. [OER Professional Development Session from the ACESSE Project] Retrieved from http://stemteachingtools.org/pd/sessione
[4] National Resource Council. (2014). *Developing Assessments for the Next Generation Science Standards.* Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessments and Board on Science Education, J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors*. Division of Social Sciences and Education. Washington, DC: The National Academies Press.
[5] National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards.* Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessment and Board on Science Education. J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors*. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

need multiple – and varied – assessment opportunities to demonstrate their competence on the performance expectations for a given grade level.

- Effective evaluation of three-dimensional science learning requires more than a one-to-one mapping between the NGSS performance expectations and assessment tasks. More than one assessment task may be needed to adequately assess students' mastery of some performance expectations, and any given assessment task may assess aspects of more than one performance expectations. In addition, to assess both understanding of core knowledge and facility with a practice, assessments may need to probe students' use of a given practice in more than one disciplinary context. Assessment tasks that attempt to test practices in strict isolation from one another may not be meaningful as assessments of the three-dimensional science learning called for by the NGSS. (Developing assessments for NGSS, NRC, pp.44-46)

How: The amount of information that has been generated around designing and creating three-dimensional assessment tasks to meet the conclusions laid out above by the National Research Council has been overwhelming. The following free resources are available through STEM teaching tools to help you navigate this flood of information and translate it into your classroom. You should start by familiarizing yourself with the following STEM Teaching Tools[6]:

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

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

1. Identify specific learning goals for the desired assessment
2. Brainstorm assessment scenarios that involve phenomena that clearly foreground the identified learning goals
3. Prioritize and select a scenario that best fits the following criteria:
    a. it should allow students from non-dominant communities (e.g., ELLs, students from poverty-impacted communities) to fully engage with the task,
    b. it should involve a compelling phenomenon related to one or more of the DCIs being assessed—and not feel like a test-like task,
    c. it should be quickly understandable by students, and
    d. it should lend itself to a broad range of science and engineering practices.

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

4. The task formats (practice briefs 30 and 41) provide detailed guidance on how to design assessment components that engage students in the science and engineering practices. Identify the practices that relate to the scenario and use the task formats to craft assessment components
5. Write hypothetical student responses for each prompt: some that reflect limited, partial, and full levels of understanding
6. Share tasks with colleagues and ask for feedback about the alignment of goals, scenarios, and hypothetical student responses

Common Misconceptions

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

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

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

Multi Layered System of Supports (MLSS)

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

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

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

Culturally and Linguistically Responsive Instruction

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

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

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

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

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

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

STANDARDS BREAKDOWN

Physical Science: Motion and Stability: Forces and Interactions

PS2-1
PS2-2
PS2-3
PS2-4
PS2-5

Students who demonstrate understanding can:

MS-PS2-1. **Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions 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
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas or principles to design an object, tool, process or system.	**PS2.A: Forces and Motion** • For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. - - - - - - - - - - - - - - - - ***Connections to Engineering,Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Connections to other DCIs in this grade-band:
MS.PS3.C

Articulation of DCIs across grade-bands:
3.PS2.A ; **HS.PS2.A**

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. *(MS-PS2-1)*

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS2-1)*

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *(MS-PS2-1)*

Mathematics -

MP.2 Reason abstractly and quantitatively. (MS-PS2-1)

6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS2-1)

6.EE.A.2 Write, read, and evaluate expressions in which letters stand for numbers. *(MS-PS2-1)*

7.EE.B.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-PS2-1)*

7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-PS2-1)*

Grade	NGSS Discipline
MS	**Physical Science 2.1**

PS2-1	**Sample Phenomena**

Sample Phenomena

PS2-1

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.

Newton's Third Law of motion which states that to every action there must be a reaction. When you flick the coin, it hits the first one (the action) and that coin then tries to move away from the first one (the reaction)

Possible Phenomena

- Crumple zones in car accidents
- Airbag deployment
- Meteorite impacts
- A Bed of Nails

Description: Special caution should be taken when sitting down or getting up from a bed of nails. In this video, Steve Spangler used a motor to lift the entire bed of nails up and down safely. Each of the nails is pushing on the participant but since there are so many nails the force is distributed safely between all of the nails. This demonstration could be used in any physics unit discussing forces and pressure.

For example, when you jump, your legs apply a force to the ground, and the ground applies an equal and opposite reaction force that propels you into the air.

Consider the flying motion of birds. A bird flies by using its wings. The wings of a bird push air downwards. Since forces result from mutual interactions, the air must also be pushing the bird upwards. The size of the force on the air equals the size of the force on the bird; the direction of the force on the air (downwards) is opposite the direction of the force on the bird (upwards). For every action, there is an equal (in size) and opposite (in direction) reaction. Action-reaction force pairs make it possible for birds to fly.

Consider the motion of a car on the way to school. A car is equipped with wheels that spin. As the wheels spin, they grip the road and push the road backwards. Since forces result from mutual interactions, the road must also be pushing the wheels forward. The size of the force on the road equals the size of the force on the wheels (or car); the direction of the force on the road (backwards) is opposite the direction of the force on the wheels (forwards). For every action, there is an equal (in size) and opposite (in direction) reaction. Action-reaction force pairs make it possible for cars to move along a roadway surface.
Watch this link to get more ideas about Newton's third law

Flymo Hover Mower Experiment watch this video Flymo Hover mower
Description: The Flymo hover mower is built on the same principles as a hovercraft. It contains a fan above the cutting blade that generates lift. This could be used as a phenomenon to explore balanced forces and gravity.

Magnetic Cannon
Description : The magnetic cannon contains four spaced neodymium magnets in a channel. Two ball bearings are placed between each ball bearing. When a new ball bearing is introduced a transfer of energy occurs and the final

ball bearing leaves with a higher initial velocity than the first. This is a great phenomenon for studying transfer of momentum and the energy of an object based on its position within a magnetic field.

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.

Conductivity
Mini Golf Design

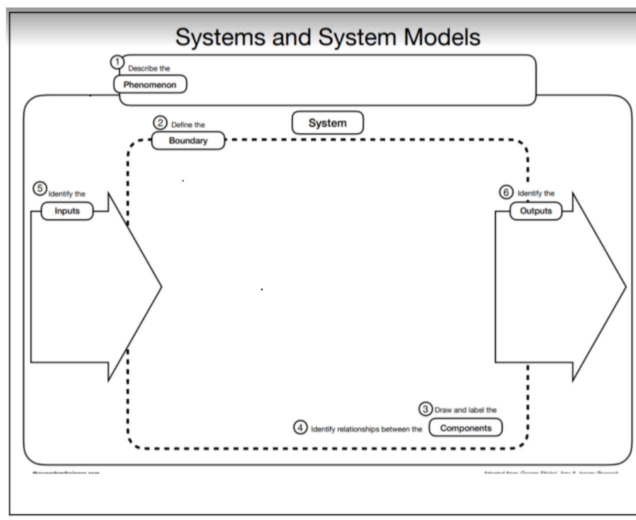
You are a mini-golf engineer preparing to open a new mini-golf course. You must design a mini-golf hole where the ball has to hit an object in order to reach the hole.
Explain how your design demonstrates Newton's Third Law.

Provide the space to type answer
(If I have a greater action force, my barrier needs to be farther away from the action force. I have a lesser action force, my barrier needs to be closer to the action force.)

Data Table:

	Force applied before hitting barrier	Force after hitting barrier	Distance ball traveled after hitting the barrier
Trial 1	5 N	5 N	
Trial 2	3 N	3 N	
Trial 3	1 N	1 N	

Text about action and reaction forces



Universal Supports	Targeted Supports
Layer 1 : • Students should understand the concepts of force • Students should know about action and reaction forces	**Layer 2 :** • Some students need extra time to understand the differences between Action and reaction forces • Some students need time to understand the concept of colliding

Common Misconceptions

- If an object is at rest, no forces are acting on the object.
- Only animated objects can exert a force. Thus, if an object is at rest on a table, no forces are acting upon it.
- Force is a property of an object. An object has force and when it runs out of force it stops moving.
- Large objects exert a greater force than small objects.
- Action-reaction forces cancel each other.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

Ask students: What knowledge and experiences have you might help us as a class explain what's happening when objects collide ?
Example: Have you seen the car collision?

Build and Bridge:
Ask students: Why would it be important for you or your community to understand what happens when objects collide ?
Example: What happens when the car hits the person or the telephone pole? What happens when the ball hits the wall?

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

Students who demonstrate understanding can:

MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*]

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

Science and Engineering Practices

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

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

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

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

Disciplinary Core Ideas

PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Crosscutting Concepts

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Connections to other DCIs in this grade-band:
MS.PS3.A ; **MS.PS3.B** ; **MS.ESS2.C**

Articulation of DCIs across grade-bands:
3.PS2.A ; **HS.PS2.A** ; **HS.PS3.B** ; **HS.ESS1.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS2-2)*
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS2-2)

Mathematics -

MP.2	Reason abstractly and quantitatively. (MS-PS2-2)
6.EE.A.2	Write, read, and evaluate expressions in which letters stand for numbers. *(MS-PS2-2)*
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-PS2-2)*
7.EE.B.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-PS2-2)*

Grade	*NGSS Discipline*
MS	**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. The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

Remembering your trips to the supermarket. It is easier to push an empty shopping cart or a full shopping cart .

Interia Tower experiment

Description : In these activities, students explore the concept of inertia. They try to keep a block tower standing when cards are pulled from between the blocks, then compare with what happens when they try the same activity with lighter objects such as paper cups. A variation is included in which students pull a large cardboard box a certain distance while being timed, then try again as people of different masses sit inside the box.

Raw or Boiled Egg Experiment

Description: This is a simple experiment to demonstrate the idea of inertia. Students could be given eggs that are both raw and boiled and they could use evidence to support the identity of the labeled eggs. In the raw egg the yolk and fluid act as independent objects and so they will continue moving when the egg is briefly stopped.

Slow motion Golf ball collision

Description: In this dramatic slow motion video a golf ball collides with a piece of steel showing a large amount of compression. Different golf balls are designed to have varying amounts of compression based on the desired behavior of the ball. In a kindergarten class golf balls or baseballs are great examples of pushes causing changes in the motion of an object. In the upper grades this could be a great example of a collision. Students could investigate the behavior of different golf balls (or clubs) and even do some designing themselves

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.

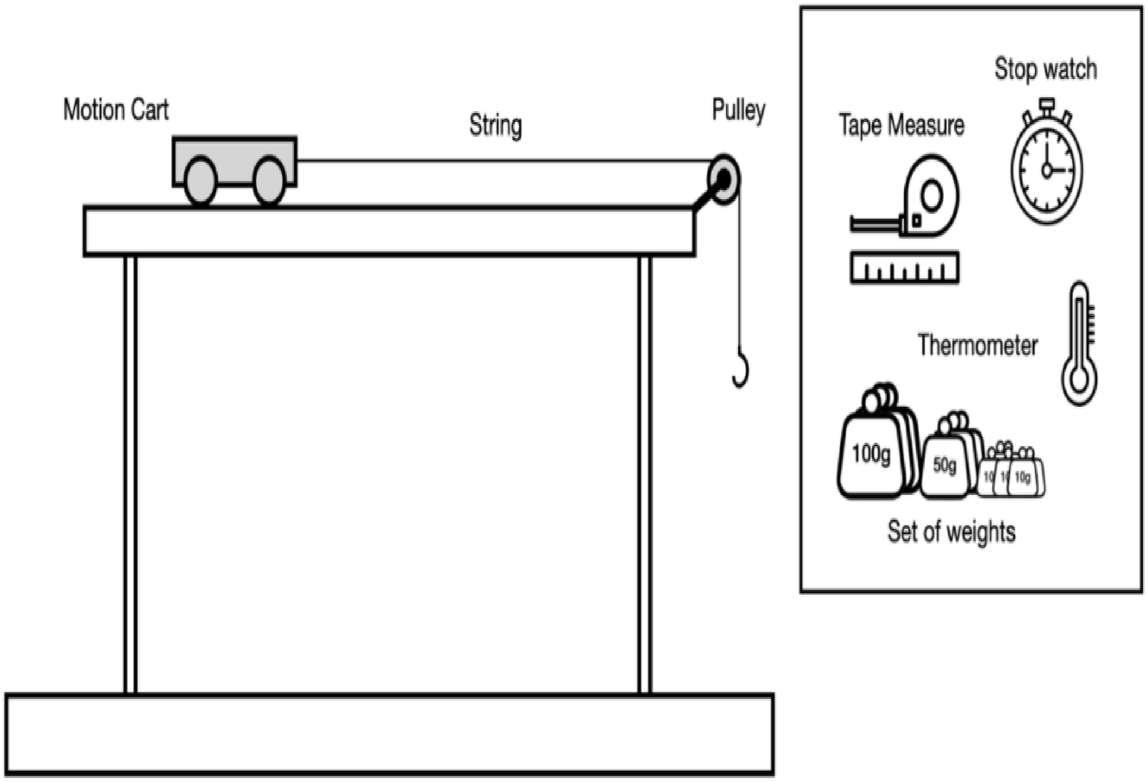
Coaster Launcher

Background

The Formula Rossa is the fastest roller coaster in the world. The coaster reaches a top speed of 240 km/hour in 4.9 seconds using a hydraulic launch system. The weight of the roller coaster when fully loaded is 3864 kg.

You will be designing an investigation to study the effect of either mass or unbalanced force on the motion of a scaled-down version of the coaster as shown below:

Figure 1: Available Lab Material



1. What is the purpose of this investigation?

   Provide space to type answer

2. Which of the following questions would you like to investigate? (Circle one)

   a. How does the mass of the rollercoaster affect the motion of the rollercoaster?

   b. How does the unbalanced force affect the motion of the rollercoaster?

3. Riders on the Formula Rossa will experience different forces depending on the number of riders and the mass of the riders. How could you modify the roller coaster so that all rides will be identical no matter how many riders are on the coaster?

   Provide space to type answer

Universal Supports	Targeted Supports
Layer 1 : ● Students explore the forces that act on objects. ● Students understand drawing a model forces acting on an object free body diagram. ● Demonstrate the models ● Basic understanding of Newton's 1st law and 2nd law	**Layer 2 :** ● Somes students need additional support on collecting and addressing the sum of factors how gravity and normal force act each other . ● Some students need more time to analyze and interpret the data ● Some group of students need more time to understand the concepts of Newton's law ●

Common Misconceptions

- If the sum of all forces adds to zero, then the object cannot move.
- An object can have a force within it that keeps it moving.
- If speed increases, then acceleration must be increasing as well.
- Forces must be exerted on a system in order for the system to maintain motion.
- Any force on an object must be in the direction of movement.
- Individual forces, not their sum, determine the motion of an object.
- If an object is moving, the sum of all forces cannot equal zero.
- Constant speed, not constant acceleration, results from constant force.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

These questions are for sense making circles. Use these questions to help guide a class discussion that brings student's own thoughts and ideas into the science classroom.

Validate and Affirm:
- What knowledge and experiences have you had that might help us as class understand the relationship between an object mass and how much force you have to exert to move it ?

Build and Bridge:
- Why does it matter to you or your community to understand the relationship between an object's mass and the forces needed to change its motion ?

Students who demonstrate understanding can:

MS-PS2-3. **Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

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
Asking Questions and Defining Problems Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	**PS2.B: Types of Interactions** • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

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

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

Common Core State Standards Connections:
ELA/Literacy -
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. *(MS-PS2-3)*
Mathematics -
MP.2 Reason abstractly and quantitatively. (MS-PS2-3)

Grade	*NGSS Discipline*
MS	**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.* Programmable Droplets from MIT **Description:** Researchers from MIT have developed a technique for moving droplets of fluid around using electric fields. This could allow biological tests and research (which normally use pumps) to move micro amounts of fluid around more economically. This design solution could be used as an anchoring or supporting phenomenon around electric charge, electromagnetic fields, and Coulomb's Law. **Programmable magnets** **Description:** Programmable magnets are engineered to have multiple magnetic regions. This allows engineers to build magnets that concentrate force, align spatially, or both attract and repel. Students can design simple solutions to human problems that use this cutting-edge technology. Candle-Powered Car Description: The candle-powered car is an application of the Seebeck Effect. This effect is the result of thermal energy conversion directly into electricity. This phenomenon can be used in elementary school to show energy conversion from heat to electricity to the kinetic energy of the car. A more detailed explanation will be required in

high school related to electron response to temperature differences in different materials. The Seeback circuit used in this candle-powered car can also be connected to a voltmeter and used as a temperature sensing thermocouple.

List of possible Phenomenon

- Two electrically charged objects of various charge intensities at various distances
- Two electrically charged objects of similar or different polarities at various distances
- Two identical magnets at various distances and relative orientations
- Two magnets of different strength, size, shape, or material
- A magnet and another object that may or may not be ferromagnetic
- A magnet and items of unknown composition
- Magnets and other materials that serve a specific purpose, such as latching a door or keeping a hook attached to a wall

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.

Plastic Ring and Rod (ID# 200-01-F01)

Introduction

Maria and Carlos are trying to make sense of a video they saw. In the video, a plastic rod and a cut out plastic ring are rubbed with a woolen hat. The plastic objects are then brought close to each other. Maria and Carlos know that surfaces of objects can become positively or negatively charged when different types of objects are rubbed with one another. They have learned that when a plastic object is rubbed with wool, the surface of the plastic object gets a negative charge and the wool gets a positive charge.

Maria and Carlos want to figure out how the charges on the objects are related to what they observe.

Question #1

Describe what happens when the plastic rod is brought near the plastic ring. Make sure to mention the type of charge on each object.

Provide space to write answer

Question #2

Write one testable question that Maria and Carlos could ask to examine the relationship between the types of charge on the objects and the direction of motion of the objects.

Remember that a testable question is one where you change one variable to observe what the effect is on another variable.

Provide space to write answer

Question #3

How does the testable question you wrote help Maria and Carlos understand the relationship between the types of charge on objects and the direction of motion of objects.

Provide space to write answer

Universal Supports	Targeted Supports
Layer 1: ● Students need to explore the strength of a magnet. ● Size of magnets ● Students need to compare the size and distances of magnets. ● Students will need to explore how electric and magnets are connected example electromagnetic induction	**Layer 2:** ● Some students may need further explanation to differentiate electric and magnetic forces. ● Some students need extra help to understand the concept of electric force and magnetic forces. ● Some students need extra time to understand the different polarities .

Common Misconceptions

- Magnetic forces only act between objects when they are in contact.
- The separation of a magnet into two halves creates two monopoles; one north and one south.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

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

Validate and Affirm :
Ask students: What knowledge and experience have you had that might help us a class understand magnetic and electric forces ?
Example: Does the size and shape of a magnet make a difference ?

Build and Bridge :
Ask students: Why does this phenomenon matter to you , to your community or others and to scientists?
Example: How do we use magnets in everyday life?

Students who demonstrate understanding can:

MS-PS2-4. **Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. • Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. - ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations.	**PS2.B: Types of Interactions** • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Connections to other DCIs in this grade-band:
MS.ESS1.A ; **MS.ESS1.B** ; **MS.ESS2.C**

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

Common Core State Standards Connections:
ELA/Literacy -
WHST.6-8.1 Write arguments focused on *discipline-specific content.* (MS-PS2-4)

Grade	*NGSS Discipline*
MS	**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.* Felix Baumgartner Space Jump World Record **Description:** In 2012 Felix Baumgartner set the World Record for skydiving from a height of 24 miles. The freefall lasted over four minutes and Felix broke the speed of sound. This phenomenon can be used to introduce the gravitational force being directed down in elementary school. This definition can be expanded upon through middle school and high school to include gravitational fields and application of Newton's Second Law of Motion. Weighing the World **Description:** The Schiehallion experiment was an attempt to measure the mass of the earth using a pendulum and a mountain (Mount Schiehallion). The mass of the mountain was approximated and the deflection of a pendulum due to the gravitational force of the mountain was measured. Students could attempt to do the calculations or even repeat the experiment on a nearby mountain.

The Gravity Light

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

More examples of possible Phenomenon

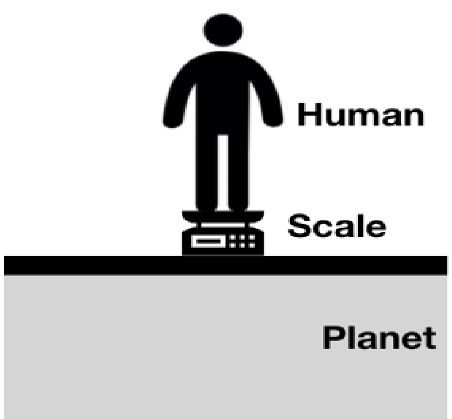
- Patterns in data/graphs illustrating that as the mass of one or both of the interacting objects increases, the magnitude of gravitational force at a given distance increases
- Patterns in data/graphs illustrating that as distance between objects of given mass increases, the strength of the gravitational forces decreases
- Comparing data from orbital speeds of satellite objects around a massive object (like the Sun) to satellite objects around a comparably less massive object (like a planet or the Moon)

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.

Interplanetary Weights

1. Label the gravitational force on the model below.



Use the Exploratorium's Your Weight on Other World's Calculator to enter your weight in the table below.

Planet	Your weight	Radius of Planet (km)	Mass of Planet (x 10^{23} kg)
Mercury		2439	3.2

Venus		6051	48.6
Jupiter		69911	18980.0
Neptune		24622	1020.0

1. Construct an argument with evidence in the space provided to support the claim that gravitational interactions are attractive and depend on the mass of the masses of the interacting objects. You should use evidence from the data table on page one.

Why do you have different weights on different planets?
• Write a claim for the change in your weight on different planets.
• Support your claim with data from the table and your knowledge of gravitational interactions.
• Share your reasoning.

CLAIM:

EVIDENCE:

REASONING:

Universal Supports	Targeted Supports
Layer 1: ● Students will need to understand gravitational interactions on earth, examples dropping things from various heights. ● Demonstrate about the gravity of earth. ● Students need to understand the gravity at different locations . ● Simulations in which student can observe patterns of movement in two or more objects interacting via gravity after altering the mass or relative distance between the objects	Layer 2: ● Some students need more understanding on comparing gravity on earth to gravity to the solar system and how the masses determine the gravity relationship. ● Some students need a detailed understanding of What impacts gravity weight on earth and on other planets . ● Students need more time toi amylase and interpret data.

Common Misconceptions

- The magnitudes of the gravitational forces exerted on interacting objects are not equal, with the smaller mass receiving a larger force and the larger mass receiving a smaller force.
- Gravitational force only applies to large objects such as planets and stars.
- There is no gravity in space.
- Gravity moves downwards.

Culturally and Linguistically Responsive Instruction

	Guiding Questions and Connections
	Build a driving question Bulletin where students can stick questions and re- address their learning through time. Revisit this board often to help students make sense of their science learning. Bring those questions to group discussion. **Validate and Affirm:** Ask students : What questions do we need to answer to test your ideas about what gravity feels like on other planets and What would mass feels on other planets? **Build and Bridge:** Ask students: Why does this phenomenon matter to you, to your community or others and to scientists? Example : Is gravity constant on planet earth and universe? Does gravity create stars and planets?

Students who demonstrate understanding can:

MS-PS2-5. **Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions. • Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.	**PS2.B: Types of Interactions** • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

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

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

Common Core State Standards Connections:
ELA/Literacy -
RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS2-5)*
WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *(MS-PS2-5)*

Grade	NGSS Discipline
MS	**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.* Programmable Droplets from MIT Description: Researchers from MIT have developed a technique for moving droplets of fluid around using electric fields. This could allow biological tests and research (which normally use pumps) to move micro amounts of fluid around more economically. This design solution could be used as an anchoring or supporting phenomenon around electric charge, electromagnetic fields, and Coulomb's Law. Cavendish Experiment **Description:** Henry Cavendish was the first scientist to measure the gravitational force between two objects in the laboratory using a gravitational torsion balance. In this video physics teacher Andrew Bennett attempts to recreate this experiment. Reading the comments section is very interesting. Pseudoscientific flat-earthers attempt to point out errors in Mr. Bennett's experiment. Students could attempt to recreate the experiment or join in the conversation.

Weighing the World

Description: The Schiehallion experiment was an attempt to measure the mass of the earth using a pendulum and a mountain (Mount Schiehallion). The mass of the mountain was approximated and the deflection of a pendulum due to the gravitational force of the mountain was measured. Students could attempt to do the calculations or even repeat the experiment on a nearby mountain.

Felix Baumgartner Space Jump World Record

Description: In 2012 Felix Baumgartner set the World Record for skydiving from a height of 24 miles. The freefall lasted over four minutes and Felix broke the speed of sound. This phenomenon can be used to introduce the gravitational force being directed down in elementary school. This definition can be expanded upon through middle school and high school to include gravitational fields and application of Newton's Second Law of Motion.

More examples of Phenomenon

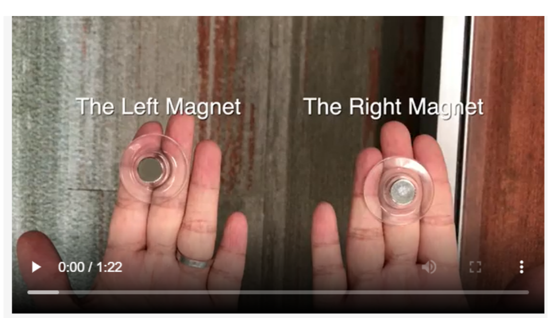
- Charged object hanging from one end of a string with another charged object nearby
- A plastic rod on a freely rotating platform with charged object nearby
- Iron filings in the vicinity of a bar magnet
- Computer simulations of fields
-

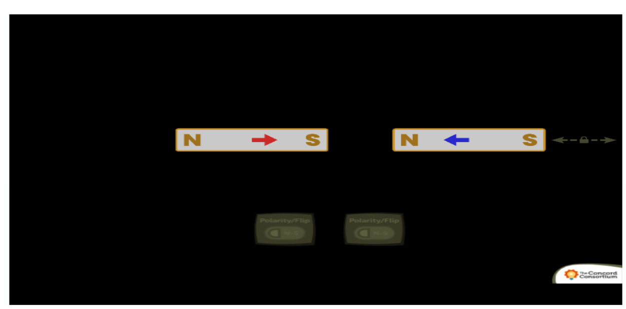
Classroom Assessment Items

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.

Magnetic note holder (ID# 212-01-FO7)

Tony's father brings home some magnetic note holders from his office. The magnets have two different sides. Tony thinks the magnets are interesting and borrows one pair to experiment with on their glass door. Here is the video of what he did.





He consults his teacher, who tells him the magnet generates a field and shows him a virtual lab. Tony wonders how to carry out an investigation to provide evidence that fields could be used to explain why two magnet holders, oriented in the proper position, are necessary to hold up the paper on the glass door.

Question #1

Using the simulation in the virtual lab, list the procedure Tony needs to take in order to provide evidence that magnets exert forces that can be explained by magnetic fields which can explain the phenomena in the video.

provide pace to type answer

Question #2

Describe the pattern of forces you observe between the magnetic objects as you change the distance between them and how this pattern provides evidence of the existence of magnetic fields.

provide space to type answer

Question #3

Using the patterns of forces you identified as evidence of the existence of magnetic fields, explain why the magnetic note holders can hold papers even when they aren't touching but cannot hold paper when one of the magnets is flipped.

provide space to type answer

Karla Plays Plinko (ID# 214-01-FO8)

Karla just got a new game called Plinko. It has a tall, flat wood board with metal pegs sticking out with a plastic cover over it. To play, you drop a hollow metal ball from the top of the board. As the ball falls down, it bumps into the metal pegs and changes direction. The ball eventually falls into one of many slots at the bottom of the board. The slots are worth different points, but one slot in the middle of the board gives 0 points. This is the "Game Over" slot.

After playing many times, Karla thinks there is something wrong with the game. The ball appears to move differently when it gets near the Game Over slot. Karla believes the peg near the Game Over slot might be magnetic, causing the ball to be attracted towards the peg and to go into the Game Over slot more often than the other slots.

How can Karla test if the ball's movement is being changed by the metal peg above the Game Over slot? Help Karla design an investigation to provide evidence this peg has a magnetic field that is changing the ball's movement. She has these materials for her experiment:

- Plinko game board with metal pegs
- Hollow metal ball
- Wood ball (same size and weight as hollow metal ball)

Answer this question using the table shown below.

Karla will drop the ball from the same place, and she won't change the peg she thinks might be magnetic. **What variable should Karla change (independent variable), and what variable should she measure (dependent variable)?**

Use the table below to answer the question "*What variable should Karla change (independent variable), and what variable should she measure (dependent variable)?*"

Provide space for writing answer

Universal Supports	Targeted Supports
Layer 1: • Explore the magnetic and electric field through investigation, for example magnetic field lines using iron filings . • Explore earth's magnetic field and to identify the impact of magnetic field	**Layer 2:** • Some students may need further instructions about what causes earth's magnetic field. • Some students need further understanding of forces between the objects and forces acting in both directions and not in one direction . • More understanding of non- contact forces . examples magnetic forces , electric forces

Common Misconceptions

- Electric/magnetic fields do not exist because they cannot be seen.
- Electric/magnetic fields exist in one dimension.
- Electric and magnetic fields are the same.
- Magnetism results from how electrons are distributed in a magnet and that the poles of a magnet are charged, with the North Pole as "positive" and the South Pole as "negative."
- A force exerted by a field stems from charged objects moving across field lines to either push or pull on other objects.

Culturally and Linguistically Responsive Instruction

	Guiding Questions and Connections
	Build a driving question Bulletin where students can stick questions and re- address their learning through time. Revisit this board often to help students make sense of their science learning. Bring those questions to group discussion. **Validate and Affirm:** Ask students : What questions do we need to answer to test your ideas about freely rotating platforms with charged objects nearby? **Build and Bridge:** Ask students : Why does this phenomenon matter to you , to your community or others and to scientists?

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.