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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 the science, or could they be learned together?
        - In what ways do the referenced mathematics and ELA standards help clarify the science performance expectations?
        - Can any of the science core ideas be included as examples in the mathematics or ELA instruction?
- Create one or more descriptions of the desired results or learning goals for the instruction integrating the three dimensions in the foundation box.
- Determine the acceptable evidence for the assessment of the desired results.
- Create the learning sequence
    - The NMIS Science document includes sample phenomena, classroom assessment items, common misconceptions, general and targeted supports, and CLR considerations that can be used to assist with this process.
- Create the summative assessment and check its alignment with the performance expectation.

Sample Phenomena

What: Natural phenomena are observable events that occur in the universe and that we can use our science knowledge to explain or predict. The goal of building knowledge in science is to develop general ideas, based on evidence, that can explain and predict phenomena. Engineering involves designing solutions to problems that arise from phenomena and using explanations of phenomena to design solutions. In this way, phenomena are the context for the work of both the scientist and the engineer.

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

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

<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

MS-PS1-1 Matter and its Interactions

Students who demonstrate understanding can:

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [*Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to predict and/or describe phenomena.	**PS1.A: Structure and Properties of Matter** • Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. • Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).	**Scale, Proportion, and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Connections to other DCIs in this grade-band:
MS.ESS2.C

Articulation of DCIs across grade-bands:
5.PS1.A ; **HS.PS1.A** ; **HS.ESS1.A**

Common Core State Standards Connections:
ELA/Literacy -

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). *(MS-PS1-1)*

Mathematics -

MP.2 Reason abstractly and quantitatively. (MS-PS1-1)
MP.4 Model with mathematics. *(MS-PS1-1)*
6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems. *(MS-PS1-1)*
8.EE.A.3 Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. *(MS-PS1-1)*

Grade	NGSS Discipline
MS	Physical Science 1.1
PS1-1	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.* OpenSciEd 7.1: Chemical Reactions and Matter: Bath Bombs - How can we make something new that was not there before? https://www.openscied.org/7-1-chemical-reactions-download/ What happens when a bath bomb is added to water (and what causes it to happen)? When solid bath bombs are added to water, they start breaking apart, and gas bubbles appear on and around them for a few minutes, until no solid is left. We observe different bath bombs and what they do when added to water and then develop individual models and explanations to show what is happening at a scale smaller than we can see. We develop an initial class consensus model, brainstorm related phenomena, develop a DQB and ideas for investigations to pursue. OpenSciEd 7.3: Metabolic Reactions - How do things inside our bodies work together to make us feel the way we do? We will hear a real case study about a girl, M'Kenna, who has recently started feeling sick all the time. Her primary complaints are that her stomach hurts after she eats and that she has diarrhea and stomach cramping. M'Kenna's Doctor note: 7.3 Lesson 1 Handout M'Kenna's Doctor's Note Audio clip of M'Kenna's symptoms: M'Kenna Symptoms Interview - 7.3 Metabolic Reactions Lesson 1 Why Does Cutting an Onion Make You Cry? Description: This phenomenon can be used to illustrate both chemical reactions and the particle nature of matter. Onions gather sulfur from the ground to form large organic compounds. When the cells in an onion are breached (during cutting or eating) they release sulfenic acid which becomes a sulfur containing gas that eventually reaches your eye. Your eyes produce tears to remove the irritant. Students could speculate on how the irritant reaches your eyes and even investigate possible solutions to this problem. This phenomenon was submitted by Brian Babulic.  Video Resources: Why Does Cutting an Onion Make You Cry? — The Wonder of Science

Fire Piston

Description: Fire pistons have been used for hundreds of years as a fire starter. Tinder is place in a seal tube and a piston is rapidly pushed into the tube. The air is compressed increasing the pressure and temperature until the ignition point of the tinder is reached. A diesel engine works in a similar fashion. This phenomenon can be used to introduce the particle model of air and temperature as a measure of the kinetic energy of particles.

Video Resources: Fire Piston — The Wonder of Science

Classroom Assessment Items

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

MS-PS1-1 Assessment - Where Does the Mass Come From? From Wonder of Science

Where Does the Mass Come From?

Introduction:

While investigating steel wool in the lab David notices an interesting phenomenon. Unlike most burning objects the mass of the steel wool increases over time. David followed steps 1-7 below to gather empirical evidence in the science lab.

1. For safety reasons goggles are worn throughout the demonstration.
2. Fine steel wool is pulled apart to create air pockets and added to a used lasagna pan.
3. The pan and steel wool are placed on an electronic balance.
4. The initial mass of the pan and steel wool together is **38.27g**.
5. The mass of the pan and steel wool are then zeroed to **0.00g** (as shown in Image 1)
6. The steel wool is ignited with a Bunsen burner and the entire demonstration is recorded by another student.
7. After 29 seconds the electronic balance reads **1.75 g** (as shown in Image 1)

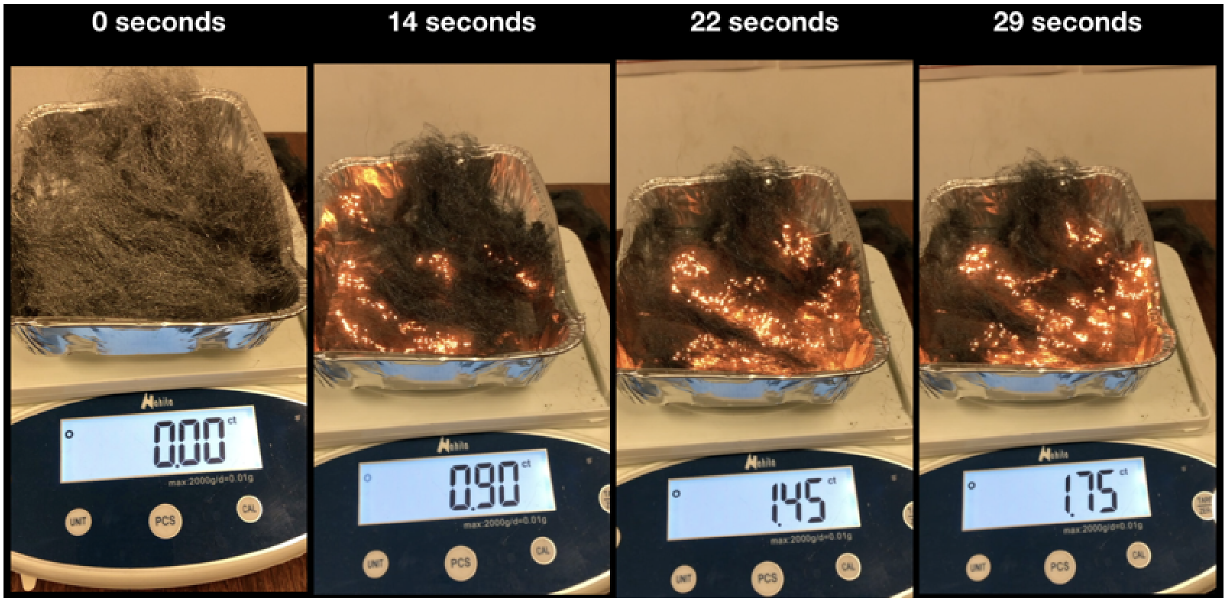


Image 1: Steel wool burned over 30 seconds

David's Explanation:

David creates the following model (Figure 2) to explain where the mass is coming from.

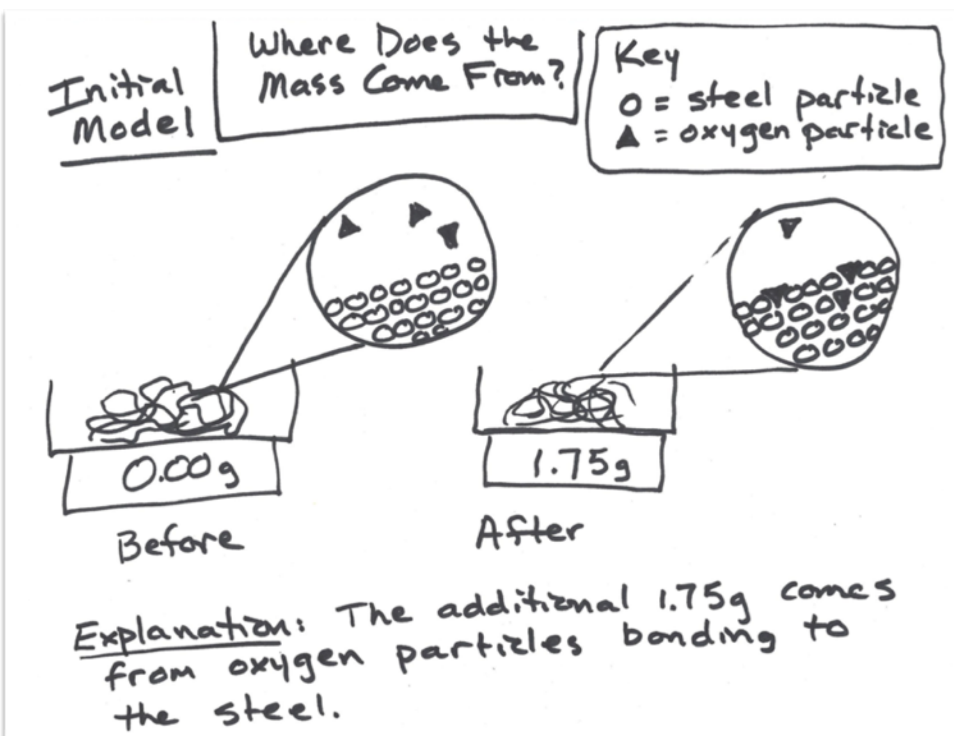


Figure 2

1. Which of the following scales are included in David's initial model? (circle all that apply)

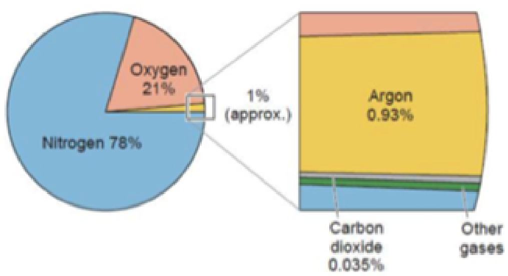
   Bulk scale   Particle scale   Atomic scale   Subatomic scale

2. According to David's initial model, what is causing the increase in mass?

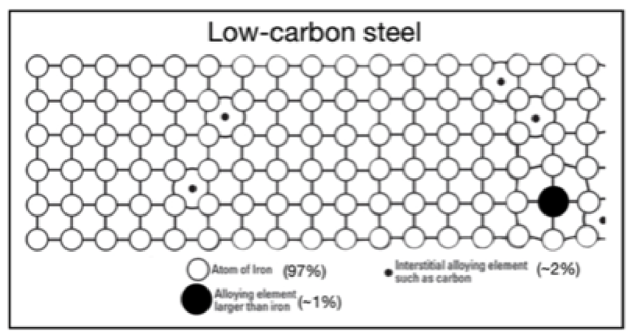
3. Do you agree with David's explanation? Why or why not?

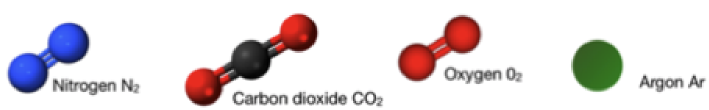
Research:

A quick internet search provides you with additional models that will help explain this phenomenon.



2.13 Component gases of the lower atmosphere





1. Draw an **atomic model** that explains the phenomenon of mass being added to burning steel wool. You may borrow ideas from David or the models above but your model must include both bulk and atomic scales. Make sure you identify and describe the components of your model.

Before	After

2. Use your **atomic model** (in question 5) to describe how the behavior of bulk substances depends on their structures at atomic and molecular levels, which are too small to see.

Universal Supports	Targeted Supports
• **Layer 1** - Create different models of molecules (ie, drawings, ball and stick, computer model) showing the relevant components and relationships, including individual atoms (elements), molecules (water and carbon dioxide), repeating subunits (crystals, polymers, plastics, carbohydrates) and substances (solid, liquid, and gases at the macro level) to show that models can vary in complexity and each can serve a different purpose. These models can show the relationship of individual atoms, which can combine to form molecules that can be made up of the same type or different types of atoms. These models can also be used to describe pure substances (either individual atoms or molecules) that react in a limited number of ways: 1. Individual atoms of the same type that are connected to form extended structures. 2. Individual atoms of different types that repeat to form extended structures (e.g., sodium chloride).	• **Layer 2** - Provide prepared manipulatives to show atoms and their interactions with each other. Be prepared to discuss how these models can represent different kinds of atoms and molecules.

3. Individual atoms that are not attracted to each other (e.g., helium).
4. Molecules of different types of atoms that are not attracted to each other (e.g., carbon dioxide).
5. Molecules of different types of atoms that are attracted to each other to form extended structures (e.g., sugar, nylon).
6. Molecules of the same type of atom that are not attracted to each other (e.g., oxygen).

Common Misconceptions

- Only one model of the atom is correct.
- The electrons in an atom orbit its nucleus like planets in our solar system
- orbit the sun.
- Electron clouds are pictures of electrons in their orbits.
- The electron cloud is like a rain cloud, with electrons inside of it like drops of
- water.
- An electron cloud has electrons in it, but the cloud itself is made of some
- other material.
- Hydrogen is a typical atom.
- Electrons are larger than protons.
- Electrons and protons are the only fundamental particles.
- The current model of the atom is the right model.
- Atoms can disappear after time.
- Atoms are microscopic versions of elements—hard or soft, liquid or gas, etc.
- Atoms can be seen with a microscope.
- Atoms move, so they are alive.
- An electron shell is hard, like an eggshell.
- Atoms “own” the electrons in their orbits.
- Pure substance cannot be broken down into other substances
- Pure substances can always be visually identified by consistency among physical features alone

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, ideas and culture into the science classroom.

	Validate and Affirm: ● Where in your life have you experienced interactions with atoms or elements or molecules? What did these interactions mean to you? - Build individual conceptual models **Build and Bridge**: ● Build a Driving Question Board where students can add their questions and re-address their learning through time. Revisit this board often to help students make sense of their science learning. - work towards a consensus model of these concepts throughout the unit.

Students who demonstrate understanding can:

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [*Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings. - - - - - - - - - - ***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.	**PS1.A: Structure and Properties of Matter** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **PS1.B: Chemical Reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.	**Patterns** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Connections to other DCIs in this grade-band:
MS.PS3.D ; **MS.LS1.C** ; **MS.ESS2.A**

Articulation of DCIs across grade-bands:
5.PS1.B ; **HS.PS1.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-PS1-2)*
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-2)

Mathematics -

MP.2	Reason abstractly and quantitatively. (MS-PS1-2)
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems. *(MS-PS1-2)*
6.SP.B.4	Display numerical data in plots on a number line, including dot plots, histograms, and box plots. *(MS-PS1-2)*
6.SP.B.5	Summarize numerical data sets in relation to their context. (MS-PS1-2)

Grade	*NGSS Discipline*
MS	**Physical Science 1.2**
PS1-2	**Sample Phenomena**
	When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.

OpenSciEd 7.1: Chemical Reactions and Matter: Bath Bombs - How can we make something new that was not there before? https://www.openscied.org/7-1-chemical-reactions-download/
What happens when a bath bomb is added to water (and what causes it to happen)?

When solid bath bombs are added to water, they start breaking apart, and gas bubbles appear on and around them for a few minutes, until no solid is left. We observe different bath bombs and what they do when added to water and then develop individual models and explanations to show what is happening at a scale smaller than we can see. We develop an initial class consensus model, brainstorm related phenomena, develop a DQB and ideas for investigations to pursue.

OpenSciEd 7.3: Metabolic Reactions - How do things inside our bodies work together to make us feel the way we do? We will hear a real case study about a girl, M'Kenna, who has recently started feeling sick all the time. Her primary complaints are that her stomach hurts after she eats and that she has diarrhea and stomach cramping.

M'Kenna's Doctor note: 7.3 Lesson 1 Handout M'Kenna's Doctor's Note
Audio clip of M'Kenna's symptoms: M'Kenna Symptoms Interview - 7.3 Metabolic Reactions Lesson 1

Elephant Toothpaste
Description: Elephant toothpaste is a dramatic chemistry demonstration that involves the decomposition of concentrated hydrogen peroxide (H2O2) into water and oxygen. Potassium iodide is used as a catalyst to speed up the reaction. Soap is added to trap the escaping oxygen gas and food coloring is often added to the experiment. This phenomenon can be using in elementary science classes to illustrate non-reversible reactions and can be studied in more detail in middle and high school.

Video Resources: Elephant Toothpaste — The Wonder of Science

Will It Conduct?
Description: Conductivity is an excellent way to classify material by their observable properties. Conducting material (e.g. metal), non-conducting material (e.g. plastic), and semi-conducting material (e.g. graphite) should all be used. A simple circuit with a lightbulb is used to determine the conductivity of different materials. These properties can be used to determine if a chemical change has occurred by testing before and after substances have been mixed. These properties can also be used in the design of an engineering solution.

Video Resources: Will It Conduct? — The Wonder of Science

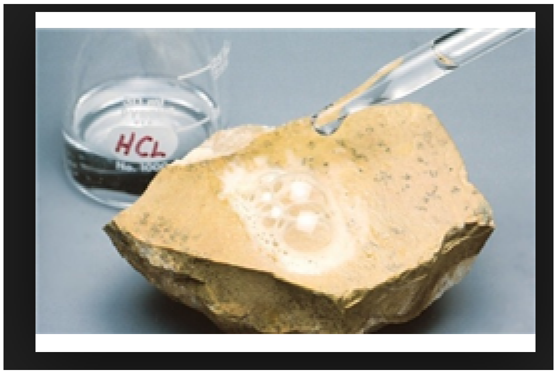
Classroom Assessment Items

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

MS-PS1-2 Assessment - Chemical Reaction and Minerals (NY) From Wonder of Science

Students working to identify minerals rubbed each sample on a streak plate (a piece of unglazed porcelain). They recorded the color of the powder left on the plate. They then added 3 drops of dilute hydrochloric acid to each sample and recorded their observations.

Student observations:
Calcite produced a white streak and bubbles with the addition of HCl. Biotite produced no streak and no change was detected with HCl. Talc produced a white streak but no change with HCl. Quartz did not produce a streak and did not change with the addition of HCl. Galena had a charcoal grey streak and produced a strong odor of rotten eggs when HCl was added. (KScarff, BSMS)



(medium.com)


(Wikipedia)

1. Organize the students' observations from above by completing the data table.

Minerals	Streak	Addition of HCl
calcite		
biotite		
talc		
quartz		
galena		

2. Analyze the data to Identify minerals that show patterns of common characteristics.

Change occurs with HCl	No Change with HCl	Minerals with Streak	Minerals without Streak

3. Interpret the data:
    a. Determine which of the minerals have a chemical reaction to hydrochloric acid and list them.

____
____
____

    b. Provide the evidence to support your claim.:

____
____
____

Universal Supports	Targeted Supports
• **Layer 1** - Discuss the characteristic chemical and physical properties, such as density, melting point, boiling point, solubility, flammability, odor) of pure substances before and after a reaction. Students should be able to organize the data (graphs, data tables, graphic organizers) in a way that they can identify similarities and differences before, during, and after the reaction. Students should use the data to determine whether this reaction was a chemical or physical change to the substance and support their interpretation of the data by describing that the change in properties of substances is related to the rearrangement of atoms in the reactants and products in a chemical reaction (e.g., when a reaction has occurred, atoms from the substances present before the interaction must have been rearranged into new configurations, resulting in the properties of new substances).	• **Layer 2** - Use prepared data sets (data tables, graphs, etc) to discuss the differences between chemical and physical properties and changes with students. Help students determine chemical and physical changes based on what they see in the data.

Common Misconceptions

- All physical changes are reversible/all chemical changes are irreversible.
- Changes of state are chemical changes.
- Chemical changes always occur when substances are mixed/dissolved.
- An increase or decrease in the temperature of a chemical system always indicates a chemical change.

- During a chemical reaction, atoms stay the same but rearrange to form new molecules.
- After a chemical reaction occurs, some of the atoms are connected to different atoms than they were in the starting molecules. (This item uses circles to represent atoms.)
- When nitric acid and copper react, the atoms detach from one another and then link together in different ways to make the molecules of the red gas and green liquid.
- When plants grow, it takes in atoms from the environment that become part of the plants.
- The mass of a glow stick will not change while the chemical reaction is occurring because the number of each type of atom inside the glow stick does not change. Some of the atoms separated from one another and then connected in different ways to form different molecules.
- The mass of a silver coin is greater after it tarnishes because the number of silver atoms stayed the same and some sulfur atoms from the air linked to the silver atoms to form silver sulfide molecules.
- Matter is not created when living organisms grow. The matter added to their bodies comes from atoms that were outside the organism.
- Law of Conservation of Mass does not apply to atoms.
- Elements can form other elements.
- All solutions are pure liquids.
- Objects float in water because they are lighter than water.
- Objects sink in water because they are heavier than water.
- Mass/volume/weight/heaviness/size/density may be perceived as equivalent.
- Wood floats and metal sinks.
- All objects containing air float.
- Liquids of high viscosity are also liquids with high density.
- Adhesion is the same as cohesion
- A “thick” liquid has a higher density than water.
- Mass and volume, which both describe an “amount of matter,” are the same property.
- Chemical changes perceived as additive, rather than interactive. After chemical change the original substances are perceived as remaining, even though they are altered.
- There is such a thing as an unbalanced chemical equation.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

- In your experience, how are interactions and reactions similar to and different from each other?
- How does adding the word chemical change these meanings for you?

Build and Bridge:

- Why does this phenomenon matter to you or your community to understand what chemical reactions are?

Build a Driving Question Board where students can add their questions and re-address their learning through time. Revisit this board often to help students make sense of their science learning.

Students who demonstrate understanding can:

MS-PS1-3. **Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.** [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [*Assessment Boundary: Assessment is limited to qualitative information.*]

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

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or now supported by evidence.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

Crosscutting Concepts

Structure and Function

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

- -

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Influence of Science, Engineering and Technology on Society and the Natural World

- The uses of technologies and any limitation 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. Thus technology use varies from region to region and over time.

Connections to other DCIs in this grade-band:
MS.LS2.A ; **MS.LS4.D** ; **MS.ESS3.A** ; **MS.ESS3.C**

Articulation of DCIs across grade-bands:
HS.PS1.A ; **HS.LS2.A** ; **HS.LS4.D** ; **HS.ESS3.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-PS1-3)
WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-PS1-3)

Grade	*NGSS Discipline*
MS	**[Physical Science 1.3]**
PS1-3	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.* OpenSciEd 7.4: Matter Cycling and Photosynthesis - Where does food come from and where does it go next? https://www.openscied.org/7-4-matter-cycling-download/ Students taste maple syrup, which comes from plants and contains food molecules. Nutrition labels show that all foods that come from plants contain food molecules. We brainstorm food we eat that we think comes from plants,

animals, or other sources. We taste maple syrup and maple sap - foods that we are surprised come from plants and watch a video of sap being extracted from a tree. We review nutrition labels for the plant foods we ate. All the plants have some food molecules. We know we get our food from eating, but how do plants get their food? Where is the food in plants coming from? We develop a model to try to explain this and develop a Driving Question Board to guide future investigations.

Precious Plastic

Description: Precious Plastics was created in 2013 by Dave Hakkens. It is a website that shares DIY plans for building machines that can recycle plastic. Plastic is recreated through a non-reversible reaction and if it isn't recycled this valuable plastic is often lost forever when it is dumped in a landfill. These plans have spawned a community of DIY plastic recyclers around the world. Even though most students lack the ability to construct these machines it may lead to simple projects like the Ecobricks project linked below.

Video Resources: [Precious Plastic — The Wonder of Science]

Slime

Description: Everyone loves slime...especially elementary students. This phenomenon is a great introduction into chemical reactions. The properties of the reactants can be compared to the properties of the products to show that a chemical reaction has occurred. In high school the chemistry of polymers and cross-linking can be explored through slime.

Video Resources: https://thewonderofscience.com/phenomenon/2018/5/13/slime

Classroom Assessment Items

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

MS-PS1-3 Assessment - Natural vs Synthetic Materials Edited From Wonder of Science

Natural vs. Synthetic Materials Summative
Instructions + Rubric
MS-PS1-3

Directions: For this summative task, you will be reading, gathering, and synthesizing information evidence to answer the following questions about the synthetic product of your choice:

1) **What is the synthetic material?**
2) **What is the importance to humans?** *(Why do humans use/make it?)*
3) **What natural resources are used to make the synthetic material?**
4) **What are the atomic structures of the reactants and the synthetic product?**
5) **How is the synthetic material made?** *(What chemical process(es) are used to create the product?)*
6) **What are the negative and positive impacts/effects of making and using the synthetic material, compared to making and/or using a more natural material with a similar function?**

Once you have completed your research, you will make a scientific poster about your findings. Your poster must include:

- all necessary requirements,
- citations for at least two sources,
- evidence that your chosen sources are reliable,
- and a neat and professional appearance.

Consult the rubric and exemplars to help guide you during this assessment.

Exemplar (Full Page PDF link)

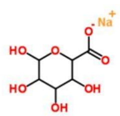
How Gummy Worms Are Made

By Sarah Smith

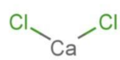
Natural Resources used to make gummy worms.
The two main active ingredients in gummy worms are Sodium Alginate and Calcium Chloride. Sodium Alginate is made from seaweed (renewable resource). Calcium chloride is made from limestone (nonrenewable resource)

Human Use
Humans use gummy worms as a sweet snack that is enjoyed by adults and kids.

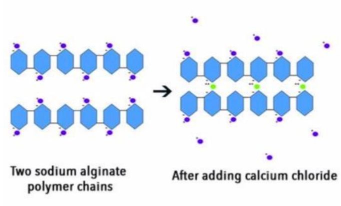
How gummy worms are made.
Factories mix Sodium Alginate and Calcium Chloride
to cause them to react chemically. As you can see below, when this is done, the calcium ions break off and cause the Sodium Alginate polymer chains to connect. This causes the worm to become "gummy."



Sodium Alginate



Calcium Chloride



Impacts on Society.

Gummy Worms	Fresh Fruit
Negative Impact: -Seaweed harvesting- takes away food from sea creatures - results in health problems if eaten too much	Negative Impact: Growing fruit trees requires deforestation to clear land; pesticide use results in pollution -if machines are used to harvest, it adds pollution
Positive impact: - Kids love them - Easy to produce in bulk	Positive impact: -healthy (has vitamins, minerals) -people enjoy them

Sources (and how I know it is reliable)

1) Burt, J. (2014). A Brief History of Gummy Bears. (Online) Bon Appetit. Available at: https://www.bonappetit.com/entertaining-style/pop-culture/article/history-gummy-bears (Accessed 11 Oct. 2018)
   - C: Article published 2014
   - R- Discusses natural resources that compose gummy worms
   - A- Author is a science writer
   - A- Quotations are from 4 studies are cited. Unbiased information.
   - P- Author is objective. Purpose: INFORM
2) Palmer, M (2017) An Australian Candy Factory Makes So Many GummyWorms They Come Out in Waterfalls (online)
   Available at: https://www.msn.com/en-ca/news/canada/an-australian-candy-factory-makes-so-many-gummy-worms-they-come-out-in-waterfalls/vp-BBHnWsM (Accessed 22 Oct. 2018)
   - C: Article published 2017
   - R- Discusses step-by-step process to make gummies
   - A- Author has a PhD in Food Science
   - A- Quotations are from multiple people/scientists in food science field
   - P- Author's opinion is not present.

Which is better for society- Worms or the natural alternative (fruit)?
Both gummy worms and fruit slices have positive and negative impacts. Because gummy worms are partially made using a non-renewable resource, I think gummy worms' negative impact is greater. Fresh fruit slices have a greater positive impact because of its health benefits to humans. Because of these reasons, I think fresh fruit is better for society.

Universal Supports	Targeted Supports
● **Layer 1** - Students will obtain and evaluate information from a variety of grade level appropriate materials in the form of text, multimedia, displays and data to address: 1. How synthetic materials are formed, the natural resources from which they are derived, and the chemical processes used to create synthetic materials from natural resources (e.g., burning of limestone for the production of concrete). 2. How the properties of the synthetic material(s) make it different from the natural resource(s) from which it was derived and how those physical and chemical properties contribute to the function of the synthetic material.	● **Layer 2** - support may include helping students understand the process to create these synthetic materials, but also can include interpretation of the materials given to them as well as support for determining the credibility, accuracy and possible bias in the given materials or data.

3. How the synthetic material (e.g. the need for concrete as a building material) satisfies a societal need or desire through the properties of its structure and function and the effects of making and using synthetic materials on natural resources and society.

Students should also be able to determine the credibility, accuracy, and possible bias of each source of information, including the ideas included and methods described.

Common Misconceptions

- All synthetic materials are made up of polymers.
- Synthetic materials are more toxic than natural materials.
- Synthetic materials are always beneficial to society.
- Synthetic chemicals are more toxic than natural chemicals.
- Organically grown food is better for you because it's all natural.
- Synthetic copies of natural chemicals are not as good for you.
- Chemical-free products are safer
- If you can't pronounce it, it's bad for you
- Organic products are better than synthetic products
- Nanoparticles are harmless
- You can lead a chemical-free life
- Man-made chemicals are inherently dangerous
- Synthetic chemicals are causing many cancers and other diseases
- Our exposure to a cocktail of chemicals is a ticking time-bomb
- It is beneficial to avoid man-made chemicals
- We are subjects in an unregulated, uncontrolled experiment

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

- What does the word synthetic mean to you, your family, or your community?
- When you hear that something is synthetic, how do you react?

Build and Bridge:

- Can you think of any examples of synthetic products that improve your life or your community's lives? - Build a Driving Question Board where students can add their questions and re-address their learning through time. Revisit this board often to help students make sense of their science learning.

Students who demonstrate understanding can:

MS-PS1-4. **Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.** [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawing and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

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

Science and Engineering Practices

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

- Develop a model to predict and/or describe phenomena.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS3.A: Definitions of Energy

- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. *(secondary)*
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. *(secondary)*

Crosscutting Concepts

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:
MS.ESS2.C

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

Common Core State Standards Connections:
ELA/Literacy -
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). *(MS-PS1-4)*

Mathematics -
6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS1-4)

Grade	NGSS Discipline
MS	Physical Science 1.4
PS1-4	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.

Supercooled Water

Description: Supercooling occurs when the temperature of a liquid is lowered below the freezing point without forming a solid. In the case of water it needs a seed crystal or a nucleation site to start forming ice. If the water has been filtered through reverse osmosis or chemical demineralization it can be safely cooled below the freezing point. Simply shaking the bottle forms solid ice.

Video Resources: [Supercooled Water — The Wonder of Science]

Ice Cube Spikes

Description: Ice cube spikes form when the exterior of the ice cube freezes first and the expanding water from the inside is forced out through a small hole or weak spot in the exterior. The phenomenon can be used to show the reversible change of freezing in elementary or the intermolecular forces between molecules in high school chemistry.

Video Resources: [Ice Cube Spikes — The Wonder of Science]

The Collapsing Train Car

Description: The collapsing train car can be used as an anchoring phenomenon on a unit related to the structure and properties of matter. The macroscopic implosion is caused by a decrease in pressure within the train car and air pressure crushing the car. To fully understand this phenomenon students must understand what is going on at the microscopic level. This phenomenon can be demonstrated at a smaller scale in the lab using an empty soda pop can (containing a small amount of water) that is heated and then inverted in water.

Video Resources: [The Collapsing Train Car — The Wonder of Science]

Classroom Assessment Items

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

MS-PS1-4 Assessment - Melting Butter From Wonder of Science

Melting butter (ID#: 045.02-e03)

A piece of solid butter is placed in a pan on a stove and gently heated, causing thermal energy to transfer to the butter until the state of the butter changed.

Butter before heating   Butter after heating

Construct a model that shows the butter particles **before** and **after** thermal energy is **transferred to** the solid butter by heating. Be sure your model includes pictures and a key to show the thermal energy and kinetic energy of the motion of the particles. Also, predict the change in the state of solid butter.

Provide space for drawing a model

Write a description of what your model shows. In your description, explain how the state of the solid butter changes after thermal energy is transferred to butter by heating.

Universal Supports	Targeted Supports
• **Layer 1** - Students will create a model to identify the relevant components, including particles and their motion, the system containing the particles, the average kinetic energy of the particles in the system, the thermal energy and temperature of the system, and the state of matter of the particles in the system. This model should describe the relationship between 1. the motion of molecules in a system and the kinetic energy of the particles in the system 2. the average kinetic energy of the particles and the temperature of the system 3. The transfer of thermal energy from one system to another, including a change in the kinetic energy of the particles in the new system, or a change in state of matter 4. The state of matter of the pure substance (gas, liquid, solid) and the particle motion (freely moving and not in contact with other particles, freely moving and in loose contact with other particles, vibrating in fixed positions relative to other particles). Students should be able to use their model to discuss and describe a variety of relationships between: 1. the addition or removal of thermal energy from a substance and the change in the average kinetic energy of the particles in the substance. 2. temperature of the system, motion of molecules in the gas phase, and collision of the molecules with other materials 3. thermal energy transfer into a system can cause an increase in kinetic energy of the particle with a. an increase in the temperature as the particles relative to each other increases b. substance can change state from a solid to a liquid or from a liquid to a gas c. an increase in the pressure as the moving molecules in gas having a greater kinetic energy colliding with surrounding substances with a greater force	• **Level 2** - Some students may need specific help regarding individual pieces within this complex modeling. You should have prepared supports to address each of the key concepts ○ particle motion ○ thermal energy transfer ○ states of matter ○ what happens in phase transitions

4. thermal energy is transfer from a substance can cause decreased kinetic energy in the system with:
    a. a decrease in the temperature as the particles relative to each other decreases
    b. substance can change state from a gas to a liquid or from a liquid to a solid
    c. a decrease in the pressure as the kinetic energy of the gas molecules decreases and the slower molecules exert less force in collisions with other molecules
5. changes in pressure of a system and changes of the states of materials in the system
    a. With a decrease in pressure, a smaller addition of thermal energy is required for particles of a liquid to change to gas because particles in the gaseous state are colliding with the surface of the liquid less frequently and exerting less force on the particles in the liquid, thereby allowing the particles in the liquid to break away and move into the gaseous state with the addition of less energy.
    b. With an increase in pressure, a greater addition of thermal energy is required for particles of a liquid to change to gas because particles in the gaseous state are colliding with the surface of the liquid more frequently and exerting greater force on the particles in the liquid, thereby limiting the movement of particles from the liquid to gaseous state..

Common Misconceptions

- Pressure and force are synonymous.
- Liquids rise in a straw because of “suction.”
- Heating air only makes it hotter.
- Heat is a substance.
- Heat is not energy.
- Temperature is a property of a particular material or object——metal is naturally cooler than plastic.
- The temperature of an object depends on its size.
- Heat and cold are different, rather than being opposite ends of a continuum.
- Boiling is the maximum temperature a substance can reach.
- Ice cannot change temperature.
- The bubbles in boiling water contain “air,” “oxygen,” or “nothing,” rather than water vapor.

- Gases are not matter because most are invisible.
- Gases do not have mass.
- Expansion of matter is due to expansion of particles rather than to increased particle spacing.
- Particles of solids have no motion.
- Melting/freezing and boiling/condensation are often understood only in terms of water.
- Particles are viewed as mini-versions of the substances they comprise.
- Particles are often misrepresented in sketches. No differentiation is made between atoms and molecules.
- Particles misrepresented and undifferentiated in concepts involving elements, compounds, mixtures, solutions and substances.
- Frequent disregard for particle conservation and orderliness when describing changes.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

- In your experiences, what do the words heat and temperature mean? How are they similar, how are they different?
- What experiences have you had with really high temperatures?

Build and Bridge:

- Why do you think it would be important for you and your community to understand how heat transfers? - Build a Driving Question Board where students can add their questions and re-address their learning through time. Revisit this board often to help students make sense of their science learning.

Students who demonstrate understanding can:

MS-PS1-5. **Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [*Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to describe unobservable mechanisms. - - - - - - - - - - - - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are regularities or mathematical descriptions of natural phenomena.	**PS1.B: Chemical Reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. • The total number of each type of atom is conserved, and thus the mass does not change.	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.

Connections to other DCIs in this grade-band:
MS.LS1.C ; **MS.LS2.B** ; **MS.ESS2.A**

Articulation of DCIs across grade-bands:
5.PS1.B ; **HS.PS1.B**

Common Core State Standards Connections:
ELA/Literacy -
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). *(MS-PS1-5)*

Mathematics -
MP.2 Reason abstractly and quantitatively. (MS-PS1-5)
MP.4 Model with mathematics. (MS-PS1-5)
6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS1-5)

Grade	*NGSS Discipline*
MS	**Physical Science 1.5**
PS1-5	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.* OpenSciEd 7.1: Chemical Reactions and Matter: Bath Bombs - How can we make something new that was not there before? https://www.openscied.org/7-1-chemical-reactions-download/ What happens when a bath bomb is added to water (and what causes it to happen)? When solid bath bombs are added to water, they start breaking apart, and gas bubbles appear on and around them for a few minutes, until no solid is left. We observe different bath bombs and what they do when added to water and then develop individual models and explanations to show what is happening at a scale smaller than we can see. We develop an initial class consensus model, brainstorm related phenomena, develop a DQB and ideas for investigations to pursue. Reaction in a Bag

Description: This video shows a chemical reaction of sodium bicarbonate (baking soda), calcium chloride (road salt), and an indicator phenol red. The chemicals react to form calcium carbonate, sodium chloride, and carbon dioxide gas. This changes the pH inside the bag resulting in a color change in the phenol red. As much air as possible should be removed from the bag as possible to show the production of the gas. This could be used as an example of a chemical reaction that releases energy (exothermic). Since the bag is sealed it could be massed before and after to show the conservation of mass (atoms). This phenomenon was submitted by Brian Babulic.

Video Resources: [Reaction in a Bag — The Wonder of Science]

Burning Steel Wool

Description: This is an excellent phenomenon to discuss chemical reactions and the conservation of mass. Steel wool is burned leading to an increase in mass. When doing this in class show the students the burning steel wool to begin with and have them predict the change in mass. Most students believe the mass will either increase or decrease. This phenomenon can be used at the beginning of a unit on chemical reactions and students can investigate their individual models. (e.g. mass comes from fire, oxygen, carbon, etc.)

Video Resources: [Burning Steel Wool — The Wonder of Science]

Classroom Assessment Items

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

[MS-PS1-5 Assessment - Battery Under Water] from Wonder of Science

Rosy put a battery in a beaker of tap water. She observed gas bubbles coming from the positive and negative ends of the battery, as shown in the video below.

https://drive.google.com/open?id=1ZBMNVCt532jY0T-JQEgIy1BDqmgCt2R7

She tested the bubbles and found that some of the bubbles were made of hydrogen gas and some were made of oxygen gas.

Draw a model that shows the chemical reaction of water changing into hydrogen and oxygen gas. Include the following descriptions for your model: 1) what happens during the reaction to the atoms of the water molecules; and 2) how your model explains why mass is conserved during this reaction.

Universal Supports	Targeted Supports
• **Layer 1** - Students will make a model to identify the type and number of molecules that make up the products and reactants for a given chemical reaction. Student should be able to describe the relationship between the components including: 1. Each molecule in each of the reactants is made up of the same type(s) and number of atoms. 2. When a chemical reaction occurs, the atoms that make up the molecules of reactants	• **Layer 2** - Supports should include chemical reaction models with manipulatives to show that the same atoms are being rearranged, not created or destroyed, in a chemical reaction and that there is no such thing as a unbalanced chemical equation

rearrange and form new molecules (i.e., products).
3. The number and types of atoms that make up the products are equal to the number and types of atoms that make up the reactants.
4. Each type of atom has a specific mass, which is the same for all atoms of that type.

Common Misconceptions

- During a chemical reaction, atoms stay the same but rearrange to form new molecules.
- After a chemical reaction occurs, some of the atoms are connected to different atoms than they were in the starting molecules.
- When plants grow, it takes in atoms from the environment that become part of the plants.
- Matter is not created when living organisms grow. The matter added to their bodies comes from atoms that were outside the organism.
- The Law of Conservation of Mass does not apply to atoms.
- Elements can form other elements.
- All solutions are pure liquids.
- There is such a thing as an unbalanced chemical equation.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:
- In your experience, how are interactions and reactions similar to and different from each other?
- How does adding the word chemical change these meanings for you?

Build and Bridge:
- Why do you think it would be important for you and your community to understand the law of conservation of mass? - Build a Driving Question Board where students can add their questions and re-address their learning through time. Revisit this board often to help students make sense of their science learning.

Students who demonstrate understanding can:

MS-PS1-6. **Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*** [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [*Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 knowledge, principles, and theories. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	**PS1.B: Chemical Reactions** • Some chemical reactions release energy, others store energy. **ETS1.B: Developing Possible Solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. *(secondary)* **ETS1.C: Optimizing the Design Solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design. *(secondary)* • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *(secondary)*	**Energy and Matter** • The transfer of energy can be tracked as energy flows through a designed or natural system.

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

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

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-PS1-6)

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-PS1-6)

Grade	*NGSS Discipline*
MS	**Physical Science 1.6**
PS1-6	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.* Reusable Heat Packs Description: This phenomenon uses a supersaturated solution of sodium acetate. Clicking the metal disc releases a small number of crystals of sodium acetate which act as nucleation sites for the crystallization of the sodium acetate into a hydrated salt. Energy is released from the crystal lattice. The heating pack can be placed in boiling water and the sodium acetate can be dissolved again. This phenomenon shows how bond energy can be released. It also shows the importance of chemical engineering and could lead to a section where students design a device (or application) of their own.

Video Resources: [Reusable Heat Packs — The Wonder of Science]

Indestructible Coating - Polyurea
Description: In this video a watermelon is covered with a polymer and survives a drop from a large tower. The polymer is formed when two reactants join to make a flexible and durable polymer known as a polyurea. The chemical reaction is exothermic, releasing heat as the reactants combine. This phenomenon could be used in a unit on chemical reactions, extended structures or chemical engineering. The company Line-X uses this polymer to make bed liners for pickup trucks.

Video Resources: [Indestructible Coating - Polyurea — The Wonder of Science]

Classroom Assessment Items

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

One of your teachers has a problem. You've noticed that anytime their coffee gets cold (below 130 degrees fahrenheit) during the first period, they stop drinking it and become very cranky. You're tasked to design something that can warm up your teacher's coffee using chemical reactions before it gets too cold! Whatever you build needs to be safe enough to work inside the classroom and it needs to fit on the teacher's desk.

1. Draw a model of a device that uses a chemical reaction to keep your teacher's coffee hot.
2. Explain how your solution works and how it uses a chemical reaction to keep your teacher's coffee hot.
3. What would be the best way to test how well a solution to this problem works?

Universal Supports	Targeted Supports

• **Layer 1** - Given a problem to solve that requires either heating or cooling, students design and construct a solution (i.e., a device). In their designs, students need to identify the components to transfer energy and the substances in the chemical reaction(s) that will be used to release or absorb thermal energy via the device. Students will also need to describe how the transfer of thermal energy between the device and other components within the system will be tracked and used to solve the given problem and the features of the given problem that are to be solved by this device through the absorption or release of thermal energy by the device via the chemical reaction. Students should keep in mind the amount and cost of the materials, safety, and the amount of time this device must function. Students test the solution for its ability to solve the problem via the release or absorption of thermal energy to or from the system. Students use the results of their tests to systematically determine how well the design solution meets the criteria and constraints, and which characteristics of the design solution performed the best. Students modify the design of the device based on the results of iterative testing, and improve the design relative to the criteria and constraints.	• **Layer 2** - Students may need support with the graphical representation of their findings, but also may need support with the development of the investigation plan. One way to support this learning could be purposeful small groupings, and opportunities for Q&A periods with the teacher.

Common Misconceptions

- Temperature is a property of a particular material or object——metal is naturally cooler than plastic.
- The temperature of an object depends on its size.
- Heat and cold are different, rather than being opposite ends of a continuum.
- Boiling is the maximum temperature a substance can reach.
- Ice cannot change temperature.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

Validate and Affirm:

- What experiences have you or your family had with having to fix a problem with only what you had on hand?
- When you are confronted with a new problem, how do you go about determining a solution?

	Build and Bridge: ● Why might it be important for your community to have engineers and repair persons? - Build a Driving Question Board where students can add their questions and re-address their learning through time. Revisit this board often to help students make sense of their science learning.

Section 3: Resources

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

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

Engaging in the Practices of Science

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Crosscutting concepts

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

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

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

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

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

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

Planning Guidance for Culturally and Linguistically Responsive Instruction

"Equity in science education requires that all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices; with access to quality space, equipment, and teachers to support and motivate that learning and engagement; and adequate time spent on science. In addition, the issue of connecting to students' interests and experiences is particularly important for broadening participation in science.[1]"

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

> **Validate/Affirm:** How can you design your classroom to intentionally and purposefully legitimize the home culture and languages of students and reverse the negative stereotypes regarding the science abilities of students of marginalized cultures and languages?
>
> **Build/Bridge:** How can you create connections between the cultural and linguistic behaviors of your students' home culture and language and the culture and language of school science to support students in creating identities as capable scientists that can use science within school and society?

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

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

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

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

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

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

Inequities are built into the systems of science education such that "students of color, students who speak first languages other than English, and students from low-income communities… have had limited access to high-quality, meaningful opportunities to learn science." Intersecting equity projects can guide the teaching and learning of science towards social justice. Science educators who engage in these projects help advance Indigenous self-determination (details) and racial justice by confronting the consequences of legacies of injustice and promoting liberatory approaches to education.

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

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

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

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

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

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

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

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

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

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