NEW MEXICO
Public Education Department

New Mexico Instructional Scope
HS Engineering, Technology, and Applications of Science Guide

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New Mexico STEM Ready! Science Standards Implementation Guide

Overview

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

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

The standards

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

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

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

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

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

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

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

For the purpose of the NMIS Science document, a process for moving from the New Mexico STEM Ready! Science Standards to classroom instruction should minimally include the following[2]:

- Read the performance expectation, clarification statement, and assessment boundary.
- Read the disciplinary core idea in the foundation box.
  - Read the applicable disciplinary core idea essay in *A Framework for K-12 Science Education*, located in chapters 5, 6, 7, and 8. As you read, consider the following questions:
    - What are some commonly held student ideas about this topic?
    - How could instruction build on helpful ideas and confront troublesome ideas?
    - What prior ideas or concepts do students need to learn to understand this core idea?
    - What level of abstractness is expected of students?
    - What are some phenomena and experiences that could provide observational or experimental evidence that the DCI is an accurate description of the natural world?
    - What representations or media would be helpful for students to use in making sense of the core idea?
- Read the science and engineering practices associated with the performance expectation.
  - Read the applicable SEP essay in *A Framework for K-12 Science Education* located in chapter 3, consider the following questions:
    - While the PE describes one SEP to be used, others will be needed in the instructional sequence, which ones and in what order will you use them?
    - How will each SEP be used to develop an understanding of the DCI?
    - What practices could students engage in to explore phenomena?
- Read the crosscutting concept associated with the performance expectation.
  - Read the applicable CCC essay in *A Framework for K-12 Science Education* located in chapter 4, consider the following questions:
    - How will the CCC indicated in the PE support the understanding of the core idea?
    - Are there other CCC that could also support learning the core idea?

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

- Read the connections box
    - When reading the connections to other DCI at this grade level that are relevant to the standard, consider the following question:
        - How can instruction be designed so that students note the connections between the core ideas?
    - When reading the articulation of DCI across grade levels that are relevant to the standard, consider the following questions:
        - Examine the standard at earlier grade levels, do they provide an adequate prior knowledge for the core ideas in the standard being reviewed?
        - Examine the standard at later grade levels, does the standard at this level provide adequate prior knowledge for the core ideas in the later standards?
    - When reading the *CCSS* in mathematics and English language arts (ELA), consider the following questions:
        - Should students have achieved these mathematics and ELA standards to engage in the learning of science, or could they be learned together?
        - In what ways do the referenced mathematics and ELA standards help clarify the science performance expectations?
        - Can any of the science core ideas be included as examples in the mathematics or ELA instruction?
- Create one or more descriptions of the desired results or learning goals for the instruction integrating the three dimensions in the foundation box.
- Determine the acceptable evidence for the assessment of the desired results.
- Create the learning sequence
    - The NMIS Science document includes sample phenomena, classroom assessment items, common misconceptions, general and targeted supports, and CLR considerations that can be used to assist with this process.
- Create the summative assessment and check its alignment with the performance expectation.

Sample Phenomena

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

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

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

<u>How:</u> We use phenomena to drive instruction to help students engage in practices to develop the knowledge necessary to explain or predict the phenomena. Therefore, the focus is not just on the phenomenon itself. It is the phenomenon plus the student-generated questions about the phenomenon that guides the learning and teaching. The practice of asking questions or identifying problems becomes a critical part of trying to figure something out.

There could potentially be many different lines of inquiry about the same phenomenon. Teachers should help students identify different aspects of the same phenomenon as the focus of their questions. Students also might ask questions about a phenomenon that motivates a line of investigation that isn't grade appropriate or might not be effective at using or building important disciplinary ideas. Teacher guidance may be needed to help students reformulate questions so they can lead to grade appropriate investigations of important science ideas.

It is important that all students – including English language learners and students from cultural groups underrepresented in STEM – are supported in working with phenomena that are engaging and meaningful to them. Not all students will have the same background or relate to a particular phenomenon in the same way. Educators should consider student perspectives when choosing phenomena and should prepare to support student engagement in different ways. When starting with one phenomenon in your classroom, it is always a good idea to help students identify related phenomena from their lives and their communities to expand the phenomena under consideration.

Not all phenomena need to be used for the same amount of instructional time. Teachers could use an anchoring phenomenon as the overall focus for a unit, along with other investigative phenomena along the way as the focus of an instructional sequence or lesson. They may also highlight everyday phenomena that relate investigative or anchoring phenomena to personally experienced situations. A single phenomenon doesn't have to cover an entire unit, and different phenomena will take different amounts of time to figure out.

The most powerful phenomena are culturally or personally relevant or consequential to students. Such phenomena highlight how science ideas help us explain aspects of real-world contexts or design solutions to science-related problems that matter to students, their communities, and society. An appropriate phenomenon for instruction should help engage all students in working toward the learning goals of instruction as described by the DCIs, SEPs, and CCCs in the foundation box of the standard.

The process of developing an explanation for a phenomenon should advance students' understanding. If students already need to know the target knowledge before they can inquire about the phenomenon, then the phenomenon is not appropriate for initial instruction. Students should be able to make sense of anchoring or investigative phenomena, but not immediately, and not without investigating it using sequences of the science and engineering practices. Phenomena do not need to be flashy or unexpected. Students might not be intrigued by an everyday phenomenon right away because they believe they already know how or why it happens. With careful teacher facilitation, students can become dissatisfied with what they believe they already know and strive to understand it in the context of the DCI that the teacher is targeting.[3]

Classroom Assessment Items

What: Classroom assessments (sometimes referred to as internal assessments) is used to refer to assessments designed or selected by teachers and given as an integral part of classroom instruction. This category of assessment may include teacher-student interactions in the classroom, observations of students, student products that result directly from ongoing instructional activities, quizzes tied to instructional activities, formal classroom exams that cover material from one or more instructional units, or assessments created by curriculum developers and embedded in instructional materials for teacher use. [4]

Classroom assessments can be designed to guide instruction (formative purposes) or to support decisions made beyond the classroom (summative purposes). Assessments used for formative purposes occur during the course of a unit of instruction and may involve both formal tests and informal activities conducted as part of a lesson. They may be used to identify students' strengths and weaknesses, assist students in guiding their own learning, and foster students' sense of autonomy and responsibility for their own learning. Assessments for summative purposes may be administered at the end of a unit of instruction. They are designed to provide evidence of achievement that can be used in decision making, such as assigning grades, making promotion or retention decisions, and classifying test takers according to defined performance categories. The results of all these assessments are evaluated by the teacher or sometimes by groups of teachers. These assessments play an integral role in students' learning experiences while also providing evidence of progress in that learning.

Why: In *Developing Assessments for the Next Generation Science Standards*, the National Research Council shared the following conclusions regarding assessing three-dimensional learning:[5]

- Measuring the three-dimensional science learning called for in the framework and the NGSS requires assessment tasks that examine students' performance of scientific and engineering practices in the context of crosscutting concepts and disciplinary core ideas. To adequately cover the three dimensions, assessment tasks will generally need to contain multiple components. It may be useful to focus on individual practices, core ideas, or crosscutting concepts in the various components of an assessment task, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given performance expectation.

- The Next Generation Science Standards require that assessment tasks be designed so they can accurately locate students along a sequence of progressively more complex understandings of a core idea and successively more sophisticated applications of practices and crosscutting concepts.

- The NGSS places significant demands on science learning at every grade level. It will not be feasible to assess all the performance expectations for a given grade level with any one assessment. Students will

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[3] Penuel, W. R., Bell, P., Neill, T., Morrison, D., & Tesoriero, G. (2018). *Selecting Anchoring Phenomena for Equitable 3D Teaching*. [OER Professional Development Session from the ACESSE Project] Retrieved from http://stemteachingtools.org/pd/sessione

[4] National Resource Council. (2014). *Developing Assessments for the Next Generation Science Standards.* Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessments and Board on Science Education, J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors*. Division of Social Sciences and Education. Washington, DC: The National Academies Press.

[5] National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards.* Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessment and Board on Science Education. J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors*. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

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

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

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

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

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

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

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

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

Common Misconceptions

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

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

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

Multi Layered System of Supports (MLSS)

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

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

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

Culturally and Linguistically Responsive Instruction

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

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

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

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

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

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

STANDARDS BREAKDOWN

Students who demonstrate understanding can:

HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.	*Connections to Engineering, Technology, and Applications of Science* **Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:
Physical Science: HS-PS2-3, HS-PS3-3

Articulation of DCIs across grade-levels:
MS.ETS1.A

Common Core State Standards Connections:
ELA/Literacy -

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *(HS-ETS1-1)*

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-ETS1-1)

MP.4 Model with mathematics. (HS-ETS1-1)

Grade	*NGSS Discipline*
HS	**Engineering, Technology, and Applications of Science 1.1**
ETS1-1	**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.

Due to the population increases, increases in pests and diseases, competition over natural resources, and climate change, agriculture production is facing challenges. Sustainable agriculture is farming in sustainable ways that meets societies food and textile needs today without compromising the ability of current or future generations to meet their needs.

Video Resources:
- FAO Policy Series: Sustainable Food and Agriculture
- FAO Policy Series: Nutrition and Food Systems
- What is Sustainable Agriculture?

Citation: Food and Agriculture Organization of the United Nations

Sustainable Agriculture Research and Education www.sare.org

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.

Sustainable Farm Challenge
GOAL: Design a sustainable farm that satisfies several key constraints found in the real world. Here is the RUBRIC for this design challenge.

STUDENT ROLES: Groups of farmers
AUDIENCE: Government officials, politicians, public figures
SCENARIO: You are a part of a group of expert agriculturalists. You live in a country that is struggling to feed its human population in a sustainable way. Several members of the government would like your group to design and create a sustainable farm model. The government plans to use your design in farms throughout the country. You may use industrial and/or sustainable agriculture practices.

DESIGN CONSTRAINTS:

Budget	$50,000	Maximum amount of money given to you to pay for the cost of the farming practices, price per seed bag, animal feed, medicine, fertilizer, pesticide, etc.
Population	10,000	Minimum amount of people you must be able to feed
Space	60 acres	Maximum amount of arable land that you can use
Emissions	350 tons of CO2	Maximum amount of pollution your farm can produce

PRODUCTS:

1. Your group will draft a proposal to the government detailing the choices you made and the reasons behind them. This document should be at least 750 words.Government officials are not experts in sustainable agriculture so be sure to explain each method along with the costs and benefits.
2. Your group will also develop at least ONE visual to support your explanation. To accomplish this work, we will explore canva as a potential graphic design tool.
3. FINALLY, YOU WILL PITCH YOUR IDEA TO THE GOVERNMENT (THE REST OF THE CLASS) IN A BABY SHARK TANK FORMAT AND THE GOVERNMENT WILL VOTE FOR THE BEST DESIGN.

PROJECT CHECKPOINTS:

- Did you satisfy the constraints?
  - Amount of money spent is under the budgeted amount
  - Amount of food produced is enough to feed the entire population
  - Sustainable farm does not take up more than the allotted space
  - Pollution emissions from the farm do not exceed maximum
- Did you create a blueprint or layout of the created sustainable farm?
- Did your sustainability plan contain the necessary rationale for the choices made during the design process?
  - Description of what sustainable agriculture is and why it is important
  - Description and explanation of the choices made in each of the four main areas (animals, crops, equipment, practices)
  - Description of the limitations of the sustainable farm
  - Areas that need to be considered that are not included in the design (transportation, nutritional needs, changing population size, etc.)

TOOL: Sustainability Calculator (make a copy for your group)
*Sustainable Agriculture: agricultural practices that do not deplete the soil faster than it can form

- Healthy soil
- Clean water
- Genetic diversity

Source Link: https://betterlesson.com/lesson/resource/3277259/prototype-activity-guide-feeding-9-billion

Universal Supports	Targeted Supports
• Provide graphic organizers to define and differentiate between qualitative and quantitative data. • Provide video and text examples of various data types. • Create small group protocols for small group discussions. • Utilize Read, Talk, Write strategy to allow students to collaborate and process their thoughts in various forms.	• Provide partially completed graphic organizers to define and differentiate between qualitative and quantitative data. • Provide individualized instruction to address student misconceptions. • In small groups, have students identify quantitative and qualitative data from examples.

Common Misconceptions

- All data types are the same.
- That quantitative (nurmerical) data is the only kind of data.
- Students think of constraints as a negative restriction as a narrowing down of the scope of an experiment or specifying variables.
- Science is the objective accumulation and testing of facts - ignoring its social nature and emphasis on explanatory ideas (this is the way textbooks describe science and the way it is most often taught in secondary education classes).
- Science is always done following the exact steps of the scientific method (this is also the way textbooks describe science and the way it is most often taught in secondary education classes).
- Design solutions should not consider human needs or behaviors.
- Global challenges are intractable or can only be solved by a global action.
- Future trends that may affect the status of present criteria/constraints cannot be predicted.
- Design solutions should not consider multiple sources.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Are all social needs and wants the same for all cultures?
- How do different cultures manage land?
- Students can discuss their social needs or wants and how they are similar to other peoples.
- Different countries manage agriculture differently and on different scales. Students can discuss how different countries view agriculture and what those agricultural needs are and how they are met.

Students who demonstrate understanding can:

HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. ▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.C: Optimizing the Design Solution** ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.	

Connections to MS-ETS1.C: Optimizing the Design Solution include:
Physical Science: HS-PS1-6, HS-PS2-3

Articulation of DCIs across grade-levels:
MS.ETS1.A ; **MS.ETS1.B** ; **MS.ETS1.C**

Common Core State Standards Connections:
Mathematics -
MP.4 Model with mathematics. (HS-ETS1-2)

Grade	*NGSS Discipline*
HS	**Engineering, Technology, and Applications of Science 1.2**
ETS1-2	**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.* ● Show a video of water or wind erosion that shows the catastrophic ramifications. ○ Erosion causing island in Canada's north to disappear ○ Wind Erosion: The Problem ○ New Mexico Water and Wind Erosion Data ● Show image below and discuss what event could have caused this. Discuss how this could impact a city or residential area if it had occurred there.

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.

In this activity students will create a solution to solve a problem facing the local or international community. Students will use the engineering design process to create a prototype of an invention that can help solve this problem. This activity can either be done in the classroom or as an at home activity.

1. Have students perform independent research on a problem that they would like to solve.
    a. Problems can be local, regional, national,or worldwide. b. Students should feel a connection to the problem.
2. Students should then brainstorm how they would solve this problem with an invention.
    a. Ask students to answer the following to help them brainstorm: who would this affect, what would it solve, when could it be used, where can it be used best, how does it work to solve the problem, and why is it important?
    b. Provide each student with the "Engineering Design Process" handout.
3. Students should sketch their design before they begin working on it.
    a. Sketches should include labels and ideas on materials to use for their prototype.
4. Students can build their prototype.
    a. This can be done at home or school. Students would need to bring in the necessary supplies to complete their prototypes.
5. Have each student present their invention.
    a. Students will discuss and question the inventions in either groups or a full class setting.
    b. Students should ask questions about each other's inventions and discuss whether they could possibly solve the problem.

Rubric:

	Target (3)	Meets (2)	Partially Meets (1)	Does Not Meet (0)
Conceptual Design	Effectively demonstrates understanding of conceptual design for a specific purpose.	Demonstrates some understanding of conceptual design but some elements do not reinforce the purpose.	Attempts to demonstrate understanding of conceptual design but the design provides limited evidence of this knowledge.	Does not demonstrate understanding of conceptual design.
Use of Materials in Prototyping	Inventively and successfully chooses materials that produce visual interest and serves to support the project's purpose.	Appropriately chooses materials that serve to support the project's purpose.	Chooses materials but some work against the purpose of the project.	Does not choose appropriate materials.
Collaboration / Discussion	Works well with others and discusses ideas in a fair, respectful, and encouraging way and is considerate of the feelings of others.	Works okay with others and discusses ideas in a fair, respectful way, but may not have been encouraging. Considers the feelings of others.	Works with others, but did not contribute a fair share of work OR was discouraging and did not consider the feelings of everyone.	Did not work well with others and/or discusses ideas in an unfair, disrespectful way.
Prototype	The prototype is thoughtfully constructed to accomplish the assigned task.	The prototype is constructed to accomplish the assigned task but has minor flaws.	The prototype was constructed but has major flaws in accomplishing the assigned task.	The prototype was not constructed to accomplish the assigned task.
Requirements	Meets all of the requirements for the project.	Meets most of the requirements for the project.	Meets some of the requirements for the project.	Does not meet the requirements for the project.
Demonstration of knowledge of Curricular Content in Discussions and Activities	Demonstrates an advanced understanding of the curricular content covered in class related to this project.	Demonstrates an adequate understanding of the curricular content covered in class related to this project.	Demonstrates limited understanding of the curricular content covered in class related to this project.	Does not demonstrate an understanding of the curricular content covered in class related to this project.
Total				/18

Web Source:
https://www.stemread.com/wp-content/uploads/2017/05/Jack-Andraka-You-Solve-the-Problem-Lesson-Plan.pdf

Universal Supports	Targeted Supports
• Give students a checklist guide to help them organize their problem solving. • In small groups, allow students to brainstorm solutions to a problem. • Provide a graphic organizer to allow students to identify different types of global problems and their impacts on humans and other organisms on Earth.	• Provide individualized interventions based on student needs. • Provide a partially completed graphic organizer to allow students to identify different types of global problems and their impacts on humans and other organisms on Earth.

- Give students a breakdown task where they are given a simple everyday problem like, what am I going to wear for today, and have them work through the problem by breaking it down into smaller parts.
    - Allow students to record their feedback in various forms (written, orally, through drawing, media, etc.)

Common Misconceptions

- Engineers drive trains
- The engineering process does not involve iterations - most products are designed well the first time.
- Engineering involves sitting at a computer all day
- All engineers need to be really good at math and science
- Engineering is only for white males.
- Engineering does not require creativity, just logic.
- All engineers do the same type of things / have similar jobs.
- The engineering process and scientific method are the same.
- Students often think of engineering as building or computer science.
- Students think of constraints as a negative restriction not as a narrowing down of the scope of an experiment or specifying variables.
- Science is the objective accumulation and testing of facts - ignoring its social nature and emphasis on explanatory ideas (this is the way textbooks describe science and the way it is most often taught in secondary education classes).
- Science is always done following the exact steps of the scientific method (this is also the way textbooks describe science and the way it is most often taught in secondary education classes).
- Global challenges can only be solved by global action.
- Global problems should be solved with an all-or-nothing approach.
- Decisions about what criteria to prioritize should not consider human wants or needs.
- Future trends that may affect the status of present criteria or constraints on a design problem cannot be predicted.

Source: https://www.cde.ca.gov/

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- How has water erosion affected you or your family?
- What examples of water erosion have you seen? Where were you when you witnessed this?
- Similar problems occur in many places around the world. Students can find examples of these similar problems occurring within different cultures and ethnic backgrounds and discuss how these problems are being solved within those cultures or ethnic backgrounds.

Students who demonstrate understanding can:

HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**

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

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.
- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Disciplinary Core Ideas

ETS1.B: Developing Possible Solutions
- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Crosscutting Concepts

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Connections to HS-ETS1.B: Developing Possible Solutions Problems include:
Earth and Space Science: HS-ESS3-2, HS-ESS3-4 **Life Science:** HS-LS2-7, HS-LS4-6

Articulation of DCIs across grade-levels:
MS.ETS1.A ; **MS.ETS1.B**

Common Core State Standards Connections:
ELA/Literacy -

RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *(HS-ETS1-3)*
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-3)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-ETS1-3)*

Mathematics -

MP.2	Reason abstractly and quantitatively. *(HS-ETS1-3)*
MP.4	Model with mathematics. (HS-ETS1-3)

Grade	*NGSS Discipline*
HS	**Engineering, Technology, and Applications of Science 1.3**
ETS1-3	**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. **Infrastructure Decay:** Much of the infrastructure in the U.S. is rapidly decaying and may soon be unsafe. Use the report card to allow students to begin exploring this problem. America's Infrastructure Report Card: America's Infrastructure Scores a C- https://infrastructurereportcard.org/
	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.

Universal Supports	Targeted Supports
• Provide students various opportunities to determine real-life problems, design solutions to those problems, and evaluate proposed solutions. • Give students a checklist guide to help them organize their problem solving. • In small groups, allow students to brainstorm solutions to a problem. • Create a graphic organizer for determining problems, finding solutions, and evaluating solutions.	• Provide individualized interventions based on student needs. • Provide a partially completed graphic organizer determining problems, finding solutions, and evaluating solutions.

Common Misconceptions

- Students often think of engineering as building or computer science.
- Students think of constraints as a negative restriction not as a narrowing down of the scope of an experiment or specifying variables.
- Science is the objective accumulation and testing of facts - ignoring its social nature and emphasis on explanatory ideas (this is the way textbooks describe science and the way it is most often taught in secondary education classes).
- Science is always done following the exact steps of the scientific method (this is also the way textbooks describe science and the way it is most often taught in secondary education classes).
- The benefits of a "good" solution always clearly outway the costs.
- A "good" solution will not have any costs.
- There are no real problems that still need to be solved.
- An engineer decides which solutions will be produced/enacted.
- Cost is always the main factor to consider in a design solution for a real-world problem.
- There is an ideal solution for each problem.

Source: https://www.cde.ca.gov/

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- What is your role in making life better? What are your cultural beliefs related to improving life for those around you and those who come after you?
- Which is most important to you personally: cost, safety, reliability, or aesthetics? Why?
- How important to you are the social, cultural, and environmental impacts of new technology/ solution?
- Research/share the scientists and engineers from different ethnic (etc.) backgrounds who have made contributions to whatever area is being discussed.

	• Emphasize that all students regardless of background can contribute to this area of study - as evidenced by the skills displayed during this unit.

Students who demonstrate understanding can:

HS-ETS1-4. **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**

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

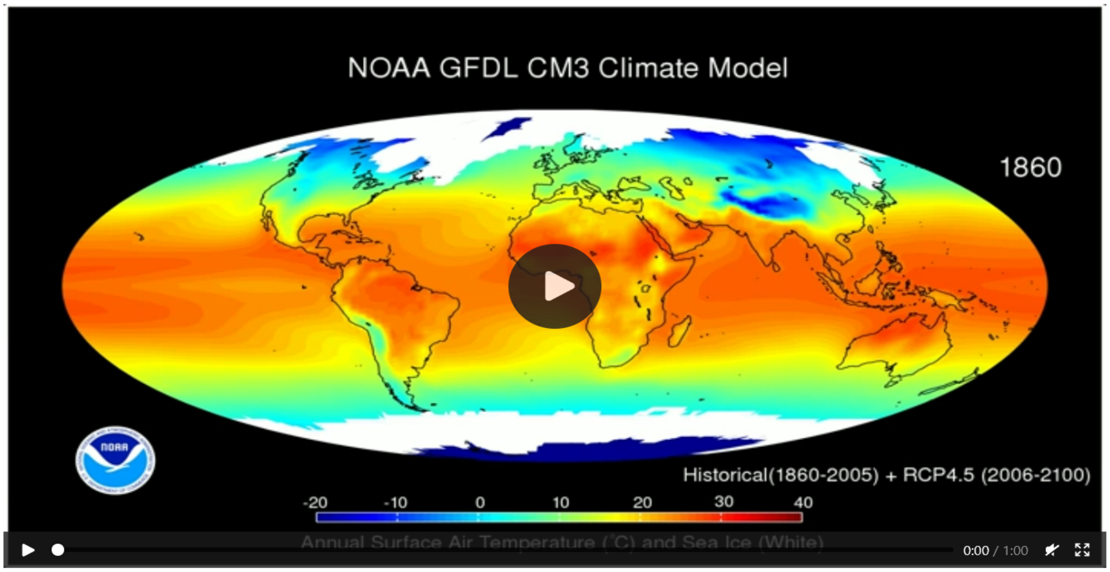
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**ETS1.B: Developing Possible Solutions** • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.

Connections to HS-ETS1.B: Developing Possible Solutions Problems include:
Earth and Space Science: HS-ESS3-2, HS-ESS3-4 **Life Science:** HS-LS2-7, HS-LS4-6

Articulation of DCIs across grade-levels:
MS.ETS1.A ; **MS.ETS1.B** ; **MS.ETS1.C**

Common Core State Standards Connections:
Mathematics -
MP.2 Reason abstractly and quantitatively. *(HS-ETS1-4)*
MP.4 Model with mathematics. (HS-ETS1-4)

Grade	*NGSS Discipline*
HS	**Engineering, Technology, and Applications of Science 1.4**
ETS1-4	**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.* **Global Climate Change Simulation:** Use the climate model as an example of using a simulation to work on solving a real-world problem. ○ Data Visualizations- Climate Predictions



Title	NOAA GFDL CM3 Climate Model
Description	This animation shows the time evolution of annual mean surface air temperature and sea-ice cover over the historical time period (1860-2005) and projected over the 21st century (2006-2100), as simulated by the NOAA GFDL CM3 climate model. Projection over the 2006-2100 time period is based on Representative Concentration Pathway 4.5 (RCP 4.5) developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR5). Concentrations and emissions of greenhouse gases, ozone depleting substances, and short-lived air pollutants including aerosols follow a "medium-low" trajectory resulting in the net radiative forcing of 4.5 Watts per square meter (equivalent to increasing carbon dioxide alone by a factor of about 2.3x) by 2100. More information on RCP scenarios is provided on the RCP emission scenario website. More information on the GFDL CM3 model is provided on https://gfdl.noaa.gov/acpc_highlights_2010_11_donner.
Model name	Coupled Climate Model (CM 3)
Scientist(s)	Larry Horowitz
Date Created	April 2010
Visualization personnel	Paidemwoyo Munhutu, Vaishali Naik
Files	MPEG (55MB) AVI (416MB) PNG (423KB)

Classroom Assessment Items

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

To prepare for this activity, students should complete the student activity linked in the source document below. This assessment will require computer software downloaded in advance.

Around the world many people get injections of insulin to control their diabetes. Virtually all the insulin used by diabetics is produced by growing large populations of bacteria that have been genetically modified to produce insulin. Suppose you were the Bio-Engineer in charge of a factory that uses a population of bacteria that produce insulin. The containers for these bacteria can hold 10,000 organisms. Your boss needs you to have a population of at least 8,000 organisms to meet the production orders.

1. Using Avida-Ed as a model of population growth of the bacteria in the factory, how much time (how many updates) will it take before the population of bacteria reaches the necessary level? (Hint: 100x100=10,000)

Web Source: https://www.teachengineering.org/activities/view/mis_population_activity1

Universal Supports	Targeted Supports
• Guide students through tutorial or steps for exploring/using the software • Complete a practice scenario with the class to demonstrate using the software • Allow students choose a topic to simulate using the software • Provide students with a checklist for choosing their own topics to stimulate • Provide students with guided questions for deeper understanding of the simulation	• Provide targeted interventions to help students: ○ Using the software - provide videos and click sheets showing use (provide one-on-one guidance)

Common Misconceptions

- You have to know a lot about coding/computer science in order to do computer modeling.
- All computer simulation programs are expensive and difficult to use.
- Engineers only use one type of model (computer or physical typically).

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- What is your role in making life better? What are your cultural beliefs related to improving life for those around you and those who come after you?
- Which is most important to you personally: cost, safety, reliability, or aesthetics? Why?
- How important to you are the social, cultural, and environmental impacts of new technology/ solution?
- Research/share the scientists, engineers, and mathematicians from different ethnic (etc.) backgrounds who have made contributions to whatever area is being discussed.
- Emphasize that all students regardless of background can contribute to this area of study - as evidenced by the skills displayed during this unit.

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.