NEW MEXICO
Public Education Department

New Mexico Instructional Scope
HS Earth and Space 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 Readers's Guide to the Next Generation Science Standards.*

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

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

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

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

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

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

Sample Phenomena

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

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

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

<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-ESS3-1. **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

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 knowledge, principles, and theories. • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**ESS3.A: Natural Resources** • Resource availability has guided the development of human society. **ESS3.B: Natural Hazards** • Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Modern civilization depends on major technological systems.

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

Articulation of DCIs across grade-bands:
MS.LS2.A ; **MS.LS4.D** ; **MS.ESS2.A** ; **MS.ESS3.A** ; **MS.ESS3.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-ESS3-1)*

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS3-1)

Mathematics -

MP.2 Reason abstractly and quantitatively. *(HS-ESS3-1)*

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *(HS-ESS3-1)*

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS3-1)*

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-ESS3-1)*

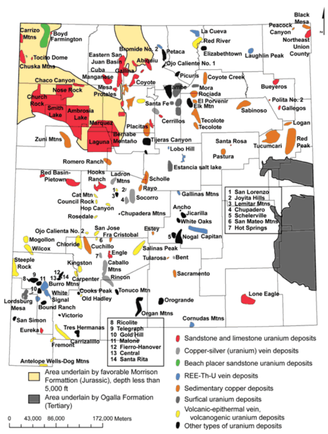
Grade	*NGSS Discipline*
HS	**Earth and Space Science 3.1**

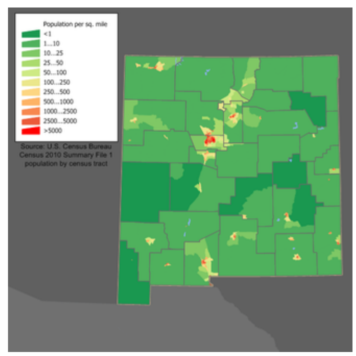
ESS3-1

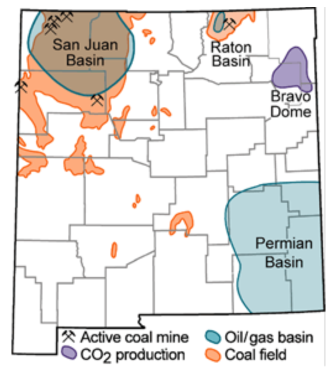
Sample Phenomena

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.

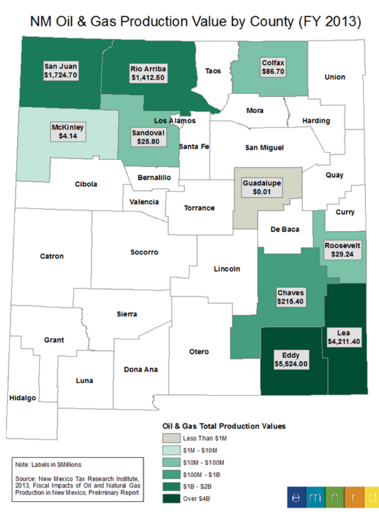
Population Density in New Mexico vs. Natural Resources Availability: Compare population density with the distribution of natural resources in New Mexico (some visuals included). Which resources seem to promote or discourage settlement? Which resources do not seem to be correlated with settlement?

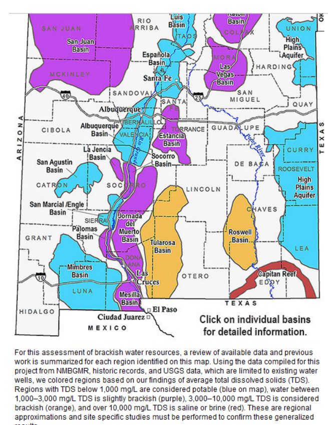






New Mexico Producing Basins, image courtesy of the New Mexico Bureau of Geology and Mineral Resources





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.

Analyzing Floods: Understanding Past Flood Events and Considering Future Flood Events in a Changing Climate

https://www.nextgenscience.org/classroom-sample-assessment-tasks

In the first half of 1993, a “perfect storm” of climatic and weather events sent a record amount of water flooding through the Upper Mississippi River Drainage Basin. Climate models predict that as the global climate changes, it is likely that there will be larger and more frequent storms, which will lead to larger flood events like the flood of 1993. In this task, students use recurrence intervals from the Mississippi River to estimate the expected size and frequency of 100-year and 500-year floods for historical data (1943 to 1992) and an imaginary future scenario where large floods are more frequent (1943 to 2021). They compare the recurrence interval versus discharge on semi-log scatterplots and consider data from global climate models to make evidence based-claims about how changing climate in a warming world will influence river discharge and flood events.

This task is adapted from:

- *McConnell, D., Steer, D., Knight, C., Owens, K., & Park, L. (2008).* The good earth: Introduction to earth Science, *p. 536. New York: McGraw Hill Higher Education.*

- *Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., Kim, H., and Kanae, S. (2013). Global flood risk under climate change.* Nature Climate Change, *3, 816–821.*

- *The Weather Channel. The Mississippi River Flood of 1993. Available at: www.weather.com/encyclopedia/flood/miss93.html. Last accessed: October 18, 2013.*

<u>Task Components</u>

A. Calculate the recurrence interval and percent probability for flood events on the Mississippi River at Keokuk, IA, for the time range of 1941–92, a 49-year range (Attachment 1). This dataset ends the year prior to the 1993 Mississippi River flood and represents historical data (McConnell et al., p. 313). Plot the discharge versus recurrence interval (RI) on the semi-log grid provided in Attachment 3. Draw a straight line through the plotted points with RI values of 2 or more and use that line to estimate the size of 100-year and 500-year floods for this river measuring station at Keokuk (McConnell et al., p. 313). Describe why your graphical representation of the flood events can be used to estimate the size of 100-year and 500-year floods for this measuring station.

- Additional Option for Students Taking Algebra 2:
  - In addition to plotting the discharge versus RI on the semi-log grid provided, plot the discharge versus RI on traditional graph paper and use that equation to calculate the 100-year and 500-year flood values. Calculate the trendline (line of best fit) equation for each scatterplot either using paper and pencil calculations or using graphing technology, such as a spreadsheet program or a graphing calculator. Compare and contrast the equations that were calculated. Consider whether one scatterplot is more accurate or easier to calculate. Using your scatterplots as evidence, construct an argument for which, if either, scatterplot allows for easier estimation of the size of floods for this river.

B. The amount of discharge of a 100-year flood is used by the public to predict whether a home is at risk of flooding (i.e., within the area affected by a 100-year flood) or not at risk of flooding (i.e., outside of the area affected by a 100-year flood). The discharge of the 1993 Mississippi flood at Keokuk, IA, was 446,000 cubic feet/second. Consider the recurrence interval and percent probability of the 1993 flood. Using observations based on your scatterplot, construct an argument for how this natural hazard event is likely to have changed how homeowners decide whether their homes are in danger of flood damage and where builders may decide to construct new homes in the future.

C. Attachment 2 imagines a future where large floods like the 1993 flood on the Mississippi River are more common. Calculate the recurrence interval and percent probability for the past flood events and the seven imaginary future flooding events on the Mississippi River at Keokuk, Iowa for the time range of 1941-2021, an 80-year time range (Attachment 1). Plot the discharge versus recurrence interval (RI) on the semi-log grid provided. Draw a straight line through the plotted points with RI values of 2 or more and use that line to estimate the new size of 100-year and 500-year floods in this imaginary future scenario. Describe why this line can be used to estimate the 100- and 500-year floods in the future scenario.

- Additional Option for Students Taking Algebra 2:
  - Determine an equation for the future trend line (line of best fit) and use that equation to calculate the 100-year and 500-year flood values. On one semi-log graph, plot the equations for both of the trend lines, and consider the differences between the current trend (from Task Component A) and the possible future trend (from Task Component C). Students also will use this scatterplot for Task Component D.

D. Compare the historical and future semi-log scatterplots and use your observations of the data and trend lines to create an evidence-based prediction for the effect a changing climate could have on the size and frequency of flooding events on Mississippi River at Keokuk, IA, if weather conditions like those that lead to the 1993 become more common. As part of your forecast, make a claim about the rate of climate change in this imaginary future scenario. Describe how the evidence supports your forecast.

E. Climate scientists used historical flood data to calculate the current predicted 100-year flood discharge values for areas all around the world just like you did in Task Component A. They also created global climate models to imagine where flood events are most likely to happen, how large they would be and how often they might occur in the next 100 years as the climate warms. They use these models to calculate a future 100-year discharge value just like you did in Task Component C. Scientists compared the historic and future world 100-year flood data values as you did when you compared your two scatterplots, and the results of the comparison model are shown in Attachment 4.

- Use the model results to make an evidence-based forecast about the effects a changing climate could have on the size and frequency of flooding events in different parts of the world. As part of your forecast, make a statement about the rate of climate change predicted by the model (considering the time range chosen for the calculations). Describe how the evidence supports your forecast. In your description, compare your global forecast to the forecast you made for the Mississippi River (considering types of effects and the rate of climate change), and discuss which is more useful in predicting the effects of climate change: data from a single area somewhere in the world (regional data) or global model results.

Universal Supports	Targeted Supports
• Provide students with graphic organizers to organize their thoughts • Allow students various options as to how they share out (oral presentation, creation of a	• Individualized targeted supports • Provide detailed graphic organizers to support students keeping their science notebooks organized.

	visual or website shared via gallery walk, graphic organizer, etc.) ● Utilize Jigsaw reading strategy for the following articles ○ Minerals: ■ Mineral Resources in New Mexico (New Mexico Bureau of Geology and Mineral Resources) at Mineral Resources of New Mexico ■ New Mexico Mines Database (New Mexico Bureau of Geology and Mineral Resources) at : New Mexico Mines Database ○ Water: ■ Water Resources (New Mexico Bureau of Geology and Mineral Resources) at Water Resources ○ Energy: ■ Natural Resources Program: Energy (New Mexico Bureau of Geology and Mineral Resources) at Natural Resources Programs Energy ● Provide students with a choice board to research various topics and with various options for presenting researched information ● Utilize Read,Talk, Write strategy for the following articles on **How do natural disasters affect life in New Mexico?** ○ Flood: ■ NWS ABQ Monsoon Awareness: Flash Floods (National Weather Service) at https://www.weather.gov/abq/prepawaremonsoonflashfloods ■ Flooding in New Mexico (National Weather Service) at https://www.weather.gov/safety/flood-states-nm ■ Current events: ● Significant flooding reported in parts of New Mexico (KRQE) May 31, 2021 at Significant flooding	● Provide extension opportunities for students or additional readings to go deeper in learning, for those students with high interests.

	reported in parts of New Mexico ● Video: Woman drowns from flooding in southeast New Mexico (KOAT Action 7 News) May 31, 2021 at https://www.koat.com/article/woman-drowns-from-flooding-in-southeast-new-mexico/36587231 ● Southeastern New Mexico experiences flash flooding, closed roads (KRQE) October 1, 2019 at Southeastern New Mexico experiences flash flooding, closed roads ○ Drought: ■ Current U.S. Drought Conditions Monitor for New Mexico (NOAA/NIDIS) at Current US Drought Monitor Conditions for New Mexico ■ Current Events: ● "Severe drought conditions continue throughout New Mexico" in Santa Fe New Mexican by Sean P. Thomas; Apr 22, 2021 ● Video: New Mexico seeing longest drought it has in years (KOAT Action 7 News) by Stephanie Muñiz; April 29, 2021 at New Mexico seeing longest drought it has in years ● Video: New Mexico farmers adapt as	

drought grows harsher (NRWG/NPR) by Madison Staten; May 7, 2021 at New Mexico Farmers Adapt As Drought Grows Harsher

- Wildfires:
  - New Mexico Fire Information website at https://nmfireinfo.com/
  - New Mexico Wildfire Alerts (NewMexico.gov) at http://newmexico.gov/New_Mexico_Wildfire_Alerts.aspx
  - Current events:
    - Eastern Arizona wildfires choke New Mexico Air Quality (Santa Fe New Mexican) by Rick Ruggles; June 8, 2021 at Eastern Arizona wildfires choke New Mexico air quality
    - Video: Ricon Fire burns in Pecos Wilderness in Santa Fe National Forest (KRQE) June 11, 2021 at Rincon Fire burns in the Pecos Wilderness in Santa Fe National Forest
- Tornados
  - New Mexico Weather Hazards (National Weather Service) at https://www.weather.gov/abq/prephazards
  - Severe Weather Climatology for New Mexico (National Weather Service) at https://www.weather.gov/abq/svrwxclimo
  - Current events
    - Video/Photos: Tornado, funnel

cloud near Springer (KRQE) May 28, 2021 at Funnel clouds are seen in some NM counties
- Jaw-dropping large tornado in New Mexico (WeatherNation) May 27, 2019 at Jaw-Dropping Large Tornado in New Mexico

- Dust Storms
  - Dust storms in New Mexico (NASA Earth Observatory) April 14, 2012 at https://earthobservatory.nasa.gov/images/77668/dust-storm-in-new-mexico
  - State warns about dust storms in southern New Mexico (Las Cruces Sun News) April 21, 2017 at State warns about dust storms in southern New Mexico
  - Current events:
    - Strong winds stir up dust storm near New Mexico-Texas border (The Weather Channel) April 15, 2021 at Strong Winds Stir Up Dust Storm Near New Mexico-Texas Border - Videos from The Weather Channel | weather.com

Common Misconceptions

- All natural resources are renewable
- Water cycles so will not run out
- Sea level rise is caused by glaciers melting
- Sea level is level (reinforced by common use of sea level as base for surveying).
- Sea level is constant - apart from changes due to ice volume (ignoring changes due to temperature or long term changes in speed of plate motions).
- Climate change is a myth. Climate fluctuates regularly. It's normal and not a concern.

- Confusing terms cause and correlate (causation vs. correlation)
- Tsunamis are immense (100's of feet tall) waves/surf (Hollywood depictions)
- Resources are universally distributed throughout the biosphere.
- Human populations have equal access to natural resources.
- Natural hazards and geologic events always negatively impact human populations.
- Human populations are not impacted by natural resource availability or natural disasters.
- The impact of resource availability on human populations has not changed with new technologies.

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

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- What do you believe about the relationship between humans and the natural world? Allow all students to share their beliefs.
- Native cultures and Mexican American cultures both have a strong connection to the natural world that emphasize symbiosis rather than use or domination. Emphasize how well this attitude aligns with this PE and conservation in general. Assist non-native/Mexican students in seeing the value of these cultural beliefs.

Students who demonstrate understanding can:

HS-ESS3-2. **Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*** [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

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

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Disciplinary Core Ideas

ESS3.A: Natural Resources

- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

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. *(secondary)*

Crosscutting Concepts

Connections to Engineering, Technology, and Applications of Science

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

- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
- Analysis of costs and benefits is a critical aspect of decisions about technology.

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
- Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Connections to other DCIs in this grade-band:
HS.PS3.B ; **HS.PS3.D** ; **HS.LS2.A** ; **HS.LS2.B** ; **HS.LS4.D** ; **HS.ESS2.A**

Articulation of DCIs across grade-bands:
MS.PS3.D ; **MS.LS2.A** ; **MS.LS2.B** ; **MS.LS4.D** ; **MS.ESS3.A** ; **MS.ESS3.C**

Common Core State Standards Connections:
ELA/Literacy -

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS3-2)

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-ESS3-2)

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-ESS3-2)

Grade	NGSS Discipline
HS	Earth and Space Science 3.2

ESS3-2

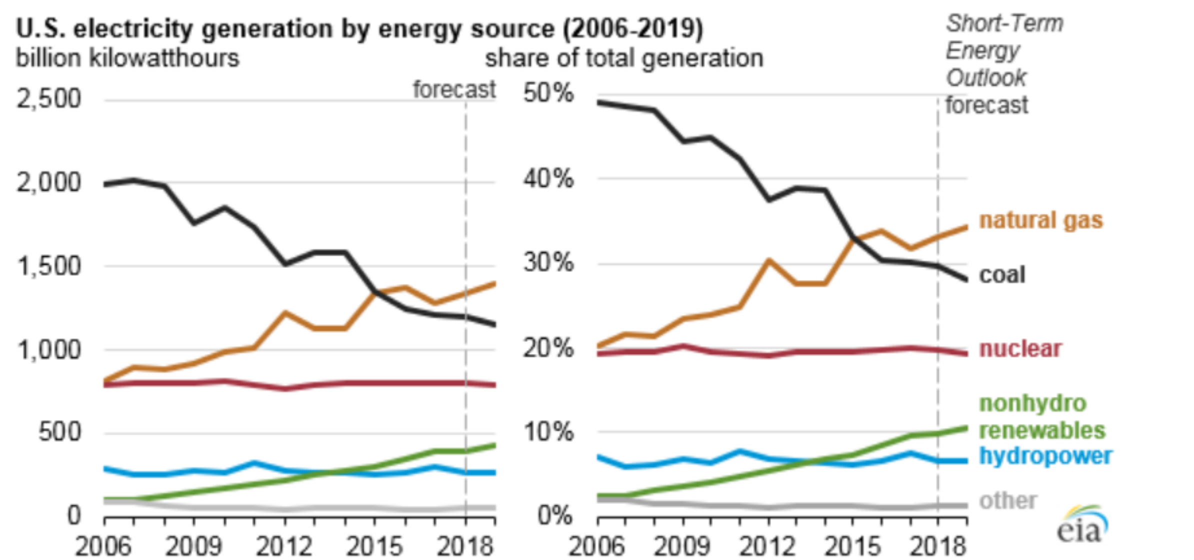
Sample Phenomena

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.

Changes in Electricity Generation Changes: Compare the graphs below. Discuss the data, patterns, and future outlooks for different sources of electricity generation.

JANUARY 22, 2018

EIA forecasts natural gas to remain primary energy source for electricity generation



Source: U.S. Energy Information Administration, *Short-Term Energy Outlook*

Source: [EIA forecasts natural gas to remain primary energy source for electricity generation - Today in Energy - US Energy Information Administration]

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.

As CO_2 emissions continue to rise, many communities have made it a goal to reduce the amount of carbon dioxide released by burning fossil fuels for energy production. If your community were to build a renewable power source to reduce the emission of CO2, which method would be the most beneficial for the overall cost? You need to evaluate the costs and benefits of using a renewable method of power generation exclusively, and then pitch it to your town board for approval. To make these claims, you will need to choose a method of energy generation (natural gas, nuclear, coal, wind, solar, geothermal, etc.), collect information, analyze the costs and benefits, and then make your proposal.

Energy and your community

The cost of powering your home and community is not always measured in the total dollars it takes to run an energy source. Other costs such as land usage, environmental impacts, and potential hazards to nearby communities also need to be considered when providing power for our modern civilization. With that in mind, is there one renewable source of power that would be a better choice for our community than another? What would be the cost if your community were to switch to one exclusive power source? Examine the information below to help you reach a conclusion about the benefit of one energy source versus continuing with the sources currently in use.

What does energy use look like in your community now?
Visit https://www.epa.gov/energy/power-profiler#/NYUP and take a look at the source of current energy for your region, and the US as a whole. Summarize the data in the table below.

Energy Source in New Mexico	
Energy type	Percentage

Wind Power

A single commercial wind turbine can generate 500,000 kWh per month and costs about 3.5 million US dollars. These large structures are 300 feet tall and require about 50 acres of clearance for each turbine produced. Unfortunately they can be responsible for harming migratory birds due to impact with the blades.

Solar or Photovoltaic (PV) Power

Many communities are now developing solar farms that can provide energy for the entire town rather than individual home owners building panels on their homes. A typical solar farm will generate about 300,000 to 450,000 kWh per month at a cost of 1 million US dollars and take up 2.5 acres of land. Annual cleaning of the panels will run about 30,000 US dollars per year.

Biomass

In biomass power plants, wood waste or other biological material is burned to produce steam that runs a turbine to make electricity, or that provides heat to industries and homes. The cost of a biomass plant depends on the amount of energy needed by your community.

1. How much energy do you need for your community? Use this link and your zip code to figure out how many housing units are in your community. Multiply this by 1000 (kw*h) to come up with your monthly energy generation needs.[Census - EDDE Deep Links]

2. Our societies have significant energy needs to function, and a widening variety of ways to generate that energy. Using the information above and this link (Fuel) contrast 2 different methods of energy production. Use the table below to organize your results.

Method	Cost Operation	Feasibility of Reuse	Environmental impact	Carbon Footprint

3. Using the table you created for each of the power generation solutions,
   a. Describe the trade-offs specific to each method

   b. Identify the solution that has the overall most favorable cost-benefit ratio

4. Compare your two chosen design solutions, based on
   a. direct($) and indirect(environmental) and geopolitical (?) costs as well as risks and benefits.
   b. how solid the evidence is on these costs and benefits
   c. constraints- how feasible will these methods be? Consider cost, safety, reliability, aesthetics, cultural and environmental effects

5. Reflect on your comparison from #3, and make an argument for one method of energy generation for your community. Make a logical argument to support your choice, acknowledging that as scientists and engineers continue to advance design the benefits of certain methods of energy generation will increase while costs and risks should decrease.

HS-ESS3-2 Assessment - What is the most beneficial energy source for your community? (NY)

Universal Supports	Targeted Supports

- Provide students with a graphic organizer to perform a cost-benefit analysis (evaluate competing design solutions) of one of the following topics. - Options for mining (a specific mineral/metal or coal) - Options for obtaining natural gas or oil - Various agricultural practice (hydroponics vs. soil or tillage practices or set-aside/conservation policies) - Create a resource list to assist students in their analysis. - Before conducting small group activity, make sure that all students understand the expectations, instructions, and their role in the performance of the task. The teacher may check for understanding by asking questions regarding the expectations and how to complete the task. - Use turn-taking strategies, timer, and model meaningful participation to avoid "knower" or a few students dominating the conversation. *S*et protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing. Involve students in setting these protocols and ground rules. - Provide sentence starters and stems that the students can use to agree, disagree, clarify, confirm, extend, and build from what has been said during a group conversation. - When conveying information during whole group discussion and conversation, limit the presentation to 5 - 10 minutes and provide visual examples for the concepts or information.	- Small group instruction for students that need assistance in - interpreting graphs and tables - Determining benefits and cost - Evaluating options/solutions

Common Misconceptions

- Some natural resources are readily available; there are no "costs" to their use.
- Recycling has solved the problem of disposable plastics (plastic water bottles/containers)
- All methods to get energy create the same amount or energy
- Conservation is always costly.
- Petroleum products are only important in automobiles.
- Technology innovations can always lead to a sustainable system.
- Earth's resources, such as fuels and water, will never be depleted.
- People must control nature more effectively.

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? • What do you believe about the relationship between humans and the natural world? Allow all students to share their beliefs. • Research/share the scientists and engineers from different ethnic (etc.) backgrounds who have made contributions to mining, energy production, etc. • Native cultures and Mexican American cultures both have a strong connection to the natural world that emphasize symbiosis rather than use or domination. Emphasize how well this attitude aligns with this PE and conservation in general. Assist non-native/Mexican students in seeing the value of these cultural beliefs.

Students who demonstrate understanding can:

HS-ESS3-3. **Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.** [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] *[Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]*

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

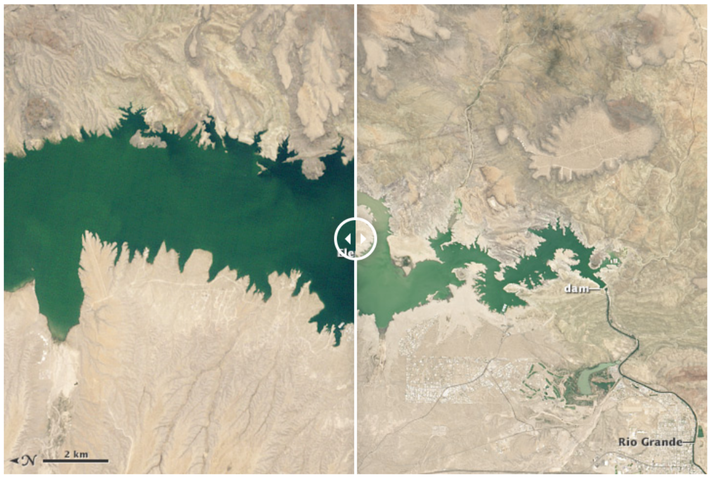
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including 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. • Create a computational model or simulation of a phenomenon, designed device, process, or system.	**ESS3.C: Human Impacts on Earth Systems** • The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Modern civilization depends on major technological systems. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. ***Connections to Nature of Science*** **Science is a Human Endeavor** • Science is a result of human endeavors, imagination, and creativity.

Connections to other DCIs in this grade-band:
HS.PS1.B ; HS.LS2.A ; HS.LS2.B ; HS.LS2.C ; HS.LS4.D ; HS.ESS2.A ; HS.ESS2.E

Articulation of DCIs across grade-bands:
MS.PS1.B ; MS.LS2.A ; MS.LS2.B ; MS.LS2.C ; MS.LS4.C ; MS.LS4.D ; MS.ESS2.A ; MS.ESS3.A ; MS.ESS3.C

Common Core State Standards Connections:
Mathematics -
MP.2 Reason abstractly and quantitatively. (HS-ESS3-3)
MP.4 Model with mathematics. (HS-ESS3-3)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 3.3**
ESS3-3	**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.* **Drought Dries Elephant Butte Reservoir**:



June 2, 1994 July 8, 2013

The Elephant Butte Reservoir is fed by the Rio Grande and is located in southern New Mexico. Elephant Butte is the largest reservoir in New Mexico and provides water for about 90,000 acres (364 square kilometers) of farmland as well as nearly half the population of El Paso, Texas.

In the summer of 2013, Elephant Butte Reservoir dwindled to its lowest level in forty years. By late July, despite the arrival of monsoon rains, the reservoir was still virtually empty. The droughts in the 1950s and 1960s reduced the water levels of Elephant Butte to its lowest, but between 1985 and 2000, the reservoir was filled nearly to capacity.

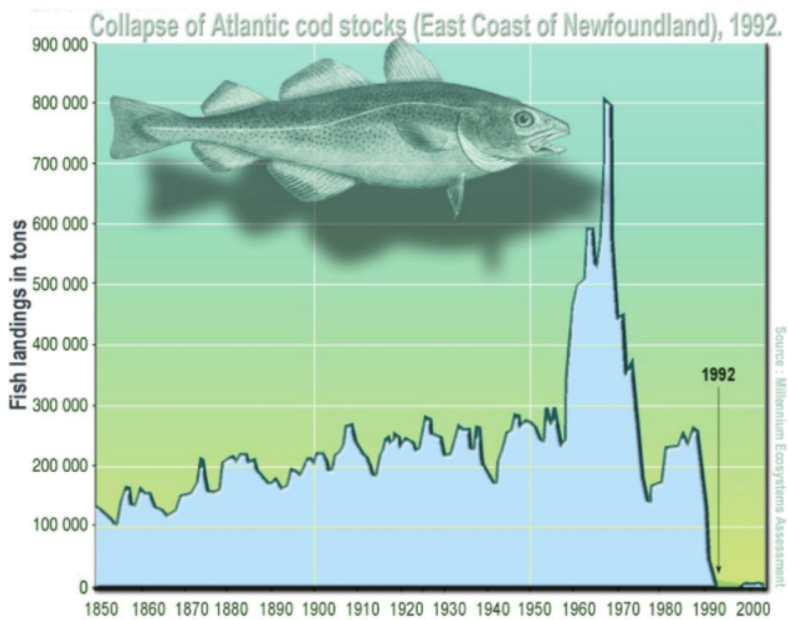
According to the Albuquerque Journal, summer rain from a southwestern monsoon and spring runoff from the mountains were not enough to make an impact on water supply.

With such limited water supplies in 2013, farmers have faced the shortest irrigation season on record, receiving just three acre-inches (308 cubic meters) instead of three acre-feet (3,700 cubic meters) of water. To meet the demand, El Paso water authorities have had to drill new wells that tap underground aquifers. The city has also increased desalinization efforts and called for voluntary water conservation measures.

From: [Drought Dries Elephant Butte Reservoir - Image of the Day]

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 the summer of 1993, when the Northern Cod biomass fell to 1% of earlier levels, the Canadian Federal Minister of Fisheries and Oceans, John Crosbie, declared a moratorium on the Northern Cod fishery, which for the preceding 500 years had largely shaped the lives and communities of Canada's eastern coast. A major factor that contributed to the depletion of the cod stocks off the shores of Newfoundland was the introduction of equipment and technology that increased the volume of landed fish. From the 1950s onwards, new technology allowed fishermen to trawl a larger area, fish more deeply and for a longer time. By the 1960s, powerful trawlers equipped with radar, electronic navigation systems and sonar allowed crews to pursue fish with unparalleled success, and Canadian catches peaked in the late 1970s and early 1980s.Cod stocks were effectively being depleted at a greater rate than could be replenished.

Also, the trawlers caught enormous amounts of non-commercial fish, which were economically unimportant but very important ecologically. This incidental catch undermines ecosystem stability, depleting stocks of important predator and prey species. With the northern cod, significant amounts of capelin – an important prey species for the cod – were caught as bycatch, further undermining the survival of the remaining cod stock. Approximately 35,000 fishermen and fish plant workers lost their jobs due to the collapse of the cod fisheries, with a devastating impact for many Newfoundland communities. The collapse of the northern cod fishery marked a profound change in the ecological, economic and socio-cultural structure of Atlantic Canada. The moratorium in 1992 was the largest industrial closure in Canadian history."

https://en.wikipedia.org/wiki/Collapse_of_the_Atlantic_northwest_cod_fishery

1. Draw a model that includes the following components: cod, capelin, fisherman, trawlers, economy, communities. Use arrows to connect the components and identify the relationships.
2. Create a spreadsheet that contains the relevant components of the ecosystem: cod, sustainability, biodiversity, technology.
3. Run simulations using the spreadsheet that models each component and its simplified mathematical relationship to other components.

Examples could include:

i. S=C*B*R*T, where S is sustainability of human populations, C is a constant, B is biodiversity, R is the natural resource, and T is a technology used to extract the resource so that if there is zero natural resource, zero technology to extract the resource, or zero biodiversity, the sustainability of human populations is also zero; and
ii. B=B1+C*T, where B is biodiversity, B1 is a constant baseline biodiversity, C is a constant that expresses the effect of technology, and T is a given technology, so that a given technology could either increase or decrease biodiversity depending on the value chosen for C.

4. Use the results of the simulation to illustrate the effects on one component by altering the others.

HS-ESS3-3 Assessment - Oysters (NY)

Universal Supports	Targeted Supports
● Provide students with examples of computational simulations and software for creating computational simulations. Allow them to explore the examples. ○ Provide a selection of different tasks/data to use to create a simulation. ● Provide a resource list for each topic that students will select for their own simulation. ○ Water in the Elephant Butte Reservoir ○ Mining copper near Silver City ○ Oil and gas extraction (Permian Basin or San Juan Basin) ○ NM Aquifers ○ Soil changes (soil survey data): Published Soil Surveys of NM: Soil Surveys by State | NRCS Soils ● Before conducting small group activity, make sure that all students understand the expectations, instructions, and their role in the performance of the task. The teacher may check for understanding by asking questions regarding the expectations and how to complete the task.	● Provide detailed anchor charts to for students that need assistance in creating their own simulation ● Provide small group intervention for students need additional assistance: ○ In using the simulation software. ○ Interpreting the resources and data provided ○ Understanding the interaction among the factors

Common Misconceptions

- Computer models are hypothetical and cannot be used to predict future events.
- Humans will continue to dominate the Earth forever - we are too smart to become extinct
- Trash taken to a landfill is destroyed / does not accumulate
- We, in the U.S., consume about the same amount of resources as humans in any other country.
- Human population size is not an environmental problem.
- Exponential human population growth and development is not linked to depletion of resources.
- Population structure is the same all over Earth.
- Simulations cannot predict real events.

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

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- How has your cultural group managed natural resources and the environment? What tools have been used to assist with finding a balance with nature?
- What do you believe about the relationship between humans and the natural world? Allow all students to share their beliefs.
- Highlight mathematicians from various cultures who have been involved in creating mathematical models or simulations related to management of natural resources, sustainability of human populations, and biodiversity.
- Emphasize that all students regardless of background can contribute to this area of study - as evidenced by the models they created related to this PE.
- Native cultures and Mexican American cultures both have a strong connection to the natural world that emphasize symbiosis rather than use or domination. Emphasize how well this attitude aligns with this PE and conservation in general. Assist non-native/Mexican students in seeing the value of these cultural beliefs.

Students who demonstrate understanding can:

HS-ESS3-4. **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

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 knowledge, principles, and theories.

- Design or refine 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

ESS3.C: Human Impacts on Earth Systems

- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

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. *(secondary)*

Crosscutting Concepts

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system.

Connections to Engineering, Technology, and Applications of Science

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

- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

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

Articulation of DCIs across grade-bands:
MS.LS2.C ; **MS.ESS2.A** ; **MS.ESS3.B** ; **MS.ESS3.C** ; **MS.ESS3.D**

Common Core State Standards Connections:
ELA/Literacy -
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS3-4)
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-ESS3-4)
Mathematics -
MP.2 Reason abstractly and quantitatively. *(HS-ESS3-4)*
HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS3-4)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS3-4)*
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-ESS3-4)*

Grade	*NGSS Discipline*
HS	**Earth and Space Science 3.4**
ESS3-4	**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.

Waste Visualized: Field trip or virtual field trip to (video of) landfill, water treatment plant, recycling center, hazardous waste facility, nuclear power plant, etc. Help students to see the magnitude of waste produced by their local community (or nearby community).

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.

Turning waste into watts
by Ming Xu

https://dnr.mo.gov/magazine/2013-winter.pdf
https://extension.colostate.edu/docs/pubs/livestk/01227.pdf

Students will read the introduction paragraph, the Science section and the Future section of the Moo Juice article. Students will be given the "Typical Anaerobic Animal Waste Generator" diagram from the article.

1. Make a pro/con T-Chart evaluating positives and negatives of Anaerobic Digestion ⟶ Energy.

2. Consider the negatives and cons listed and offer a potential solution to refine the process.

3. What else can this process be applied to convert waste into energy to minimize human impact on the environment?

HS-ESS3-4 Assessment - Moo Juice

Universal Supports	Targeted Supports
• Use turn-taking strategies, timer, and model meaningful participation to avoid "knower" or a few students dominating the conversation. • *S*et protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing. Involve students in setting these protocols and ground rules. • Provide sentence starters and stems that the students can use to agree, disagree, clarify, confirm, extend, and build from what has been said during a group conversation.	• Provide targeted individualized interventions • Provide detailed graphic organizers and anchor charts to help students organize their thoughts

Common Misconceptions

- Humans don't need to reduce their effect on the Earth.
- The earth systems can handle a lot and will always be able to take care of pollution, etc.
- No long-term changes have occurred to the Earth (water levels, temperature, etc.)
- Well-designed technological designs do not have unanticipated negative effects.
- Solutions can always eliminate the human impact.
- All constraints equally influence solutions.

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?
- What do you believe about the relationship between humans and the natural world? Allow all students to share their beliefs.
- Highlight scientists and engineers from various cultural backgrounds who have contributed to technological solutions to reduce the impact of human activity on the natural world.
- Native cultures and Mexican American cultures both have a strong connection to the natural world that emphasize symbiosis rather than use or domination. Emphasize how well this attitude aligns with this PE and conservation in general. Assist non-native/Mexican students in seeing the value of these cultural beliefs.

Students who demonstrate understanding can:

HS-ESS3-5. **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [*Assessment Boundary: Assessment is limited to one example of a climate change and its associated 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	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using computational models in order to make valid and reliable scientific claims. - ***Connections to Nature of Science*** **Scientific Investigations Use a Variety of Methods** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • New technologies advance scientific knowledge. **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based on empirical evidence. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation.	**ESS3.D: Global Climate Change** • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

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

Articulation of DCIs across grade-bands:
MS.PS3.B ; ***MS.PS3.D*** ; ***MS.ESS2.A*** ; ***MS.ESS2.D*** ; ***MS.ESS3.B*** ; ***MS.ESS3.C*** ; ***MS.ESS3.D***

Common Core State Standards Connections:
ELA/Literacy -

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS3-5)
RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *(HS-ESS3-5)*
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-ESS3-5)*

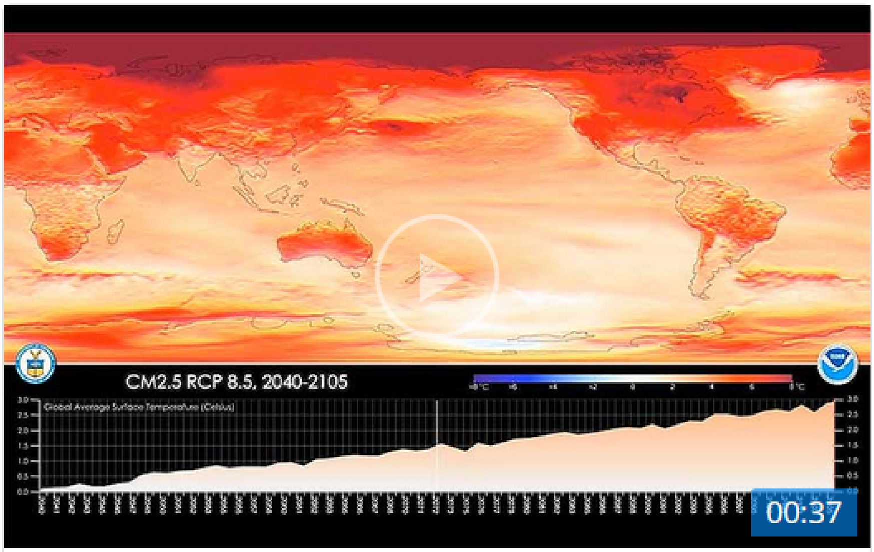
Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-ESS3-5)
HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS3-5)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS3-5)*
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS3-5)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 3.5**
ESS3-5	**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.

Model of Global Surface Temperatures:



Global Surface Temperature CM2.5, RCP 8.5 forcing

This animation shows projections for surface air temperature anomalies and global mean temperature for the years 2040 to 2105 under Representative Concentration Pathways (RCPs), RCP8.5.

Description	This animation shows projections for surface air temperature anomalies and global mean temperature for the years 2040 to 2105 under Representative Concentration Pathways (RCPs), RCP8.5.
Model name	CM2.5
Scientist(s)	Tom Delworth, Tony Rosati, Whit Anderson, Fanrong Zhang
Date Created	November 2015
Visualization personnel	Whit Anderson
Files	MPEG

NOAA: Global Fluid Dynamics Laboratory
[Visualizations – Climate Prediction – Geophysical Fluid Dynamics Laboratory]

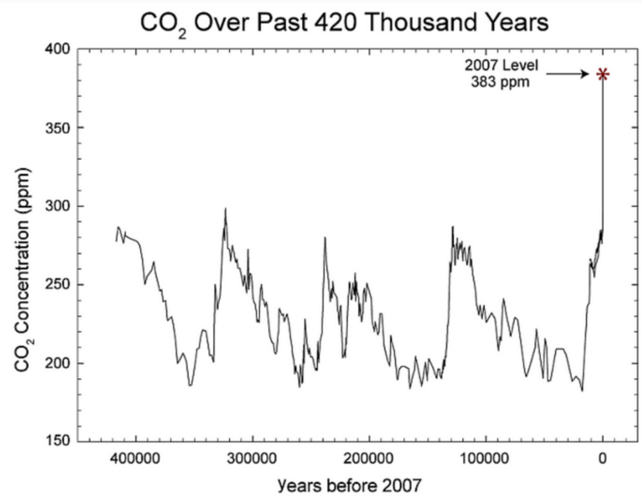
Classroom Assessment Items

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.

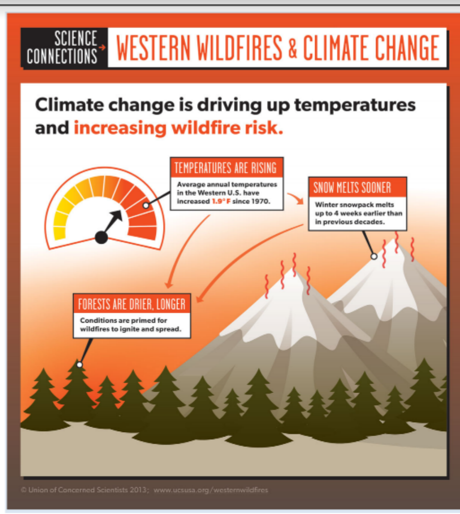
Climate Change and Wildfires

You and your family are thinking of visiting Yosemite National Park during summer break. After watching the nightly news, you discover:

Stimulus



source: Scripps Institution of Oceanography)



Source: https://www.ucsusa.org/sites/default/files/legacy/assets/images/gw/infographic-western-wildfires-and-climate-change/Infographic-Western-Wildfires-and-Climate-Change-Panel-2-Full-Size.jpg

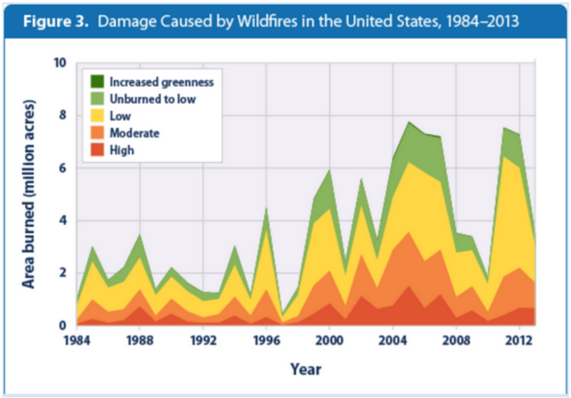


Figure 3. Damage Caused by Wildfires in the United States, 1984–2013

Source: Environmental Protection Agency

Record the patterns you see in the data sets.

Time	Carbon Dioxide

Time	Wildfires

Describe the processes that could have changed..

CAUSE	MECHANISM	EFFECTS

Assessment Rubric* - Question 1				
	Emerging	Developing	Approaching Proficiency	Excelling
Description of performance				
Sample student responses				

[HS-ESS3-5 Assessment - Climate Change & Wildfires]

Assessments adapted from the Stanford NGSS Assessment Project [http://snapgse.stanford.edu/] 'Wiggins, G. P. (1993). Assessing student performance. San Francisco: Jossey-Bass Publishers.

Universal Supports	Targeted Supports
• Set protocols and ground rules for conducting whole group and small group activity, conversation, affirming, and respectful ways of disagreeing. Involve students in setting these protocols and ground rules. • Provide sentence starters and stems that the students can use to agree, disagree, clarify, confirm, extend, and build from what has been said during a group conversation. • When conveying information during whole group discussion and conversation, limit the presentation to 5 - 10 minutes and provide visual examples for the concepts or information. • Provide students with graphic organizers	• Provide targeted individualized interventions

Common Misconceptions

- Climate change is a myth.
- Earth is primarily warmed directly by sunlight (real life experience, walk into sunlight you get warm, it is difficult to disassociate sunlight from heat coming off surrounding surfaces)
- Greenhouse warming works like greenhouses do (specifically mentioned in many texts).
- Greenhouse warming is an unproven concept (tied to politics and confusion over greenhouse warming and climate change due to human activities).
- Greenhouse warming is only due to human activities (flip side of above confusion).
- Sea level rise is caused by glaciers melting
- Sea level is level (reinforced by common use of sea level as base for surveying).
- Sea level is constant - apart from changes due to ice volume (ignoring changes due to temperature or long term changes in speed of plate motions).
- The 'Ice Ages' happened in the past and are now over (common text book and science education movie terminology, as well as Hollywood movies and original hypothesis).
- The present Ice Caps have always existed on Earth, although their size has changed through time (few texts specifically mention that ice ages are the exception, not the rule).
- Weather and climate are synonymous
- Climate change is caused by the growing hole in the ozone layer.
- Most of the sun's energy is in the form of ultraviolet (UV) energy.
- CO_2 is the only greenhouse gas
- Climate change is only the result of anthropogenic factors.

- Climate change models cannot predict changes to physical parameters or chemical composition of the atmosphere, geosphere, hydrosphere, or cryosphere.

Source: California Department of Education

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- What do you believe about climate change? Why do you believe as you do? What factors have influenced your beliefs?
- What is the role of science in shaping your beliefs? Do you trust scientists and research data? What factors have influenced your beliefs?
- What do you believe about the role of humans in shaping the future?
- What do you believe about the relationship between humans and the natural world? Allow all students to share their beliefs.
- Highlight the diverse cultural backgrounds of scientists, engineers, and mathematicians working on models of climate change.
- Emphasize each student's ability to contribute to this area of research based on their participation in activities from this unit.
- Native cultures and Mexican American cultures both have a strong connection to the natural world that emphasize symbiosis rather than use or domination. Emphasize how well this attitude aligns with this PE and conservation in general. Assist non-native/Mexican students in seeing the value of these cultural beliefs.

Students who demonstrate understanding can:

HS-ESS3-6. **Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]

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 a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	**ESS2.D: Weather and Climate** • Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. *(secondary)* **ESS3.D: Global Climate Change** • Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Connections to other DCIs in this grade-band:
HS.LS2.B ; **HS.LS2.C** ; **HS.LS4.D** ; **HS.ESS2.A**

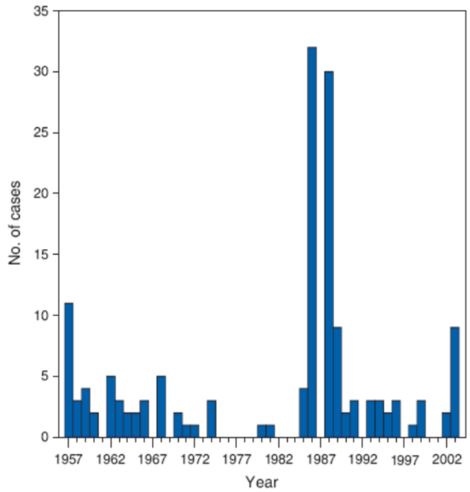
Articulation of DCIs across grade-bands:
MS.LS2.C ; **MS.ESS2.A** ; **MS.ESS2.C** ; **MS.ESS3.C** ; **MS.ESS3.D**

Common Core State Standards Connections:
Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS3-6)
MP.4	Model with mathematics. (HS-ESS3-6)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS3-6)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS3-6)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS3-6)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 3.6**
ESS3-6	**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.* **Malaria in New Mexico?** Locally acquired Malaria cases are on the rise in the U.S. Warming temperatures in New Mexico create conditions that may further increase the incidence of this once-thought-to-be eradicated disease.

FIGURE 1. Number of locally acquired malaria cases, by year — United States, 1957–2003



Locally acquired mosquito-transmitted Malaria: A guide for investigations in the U.S. (CDC)
https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5513a1.htm

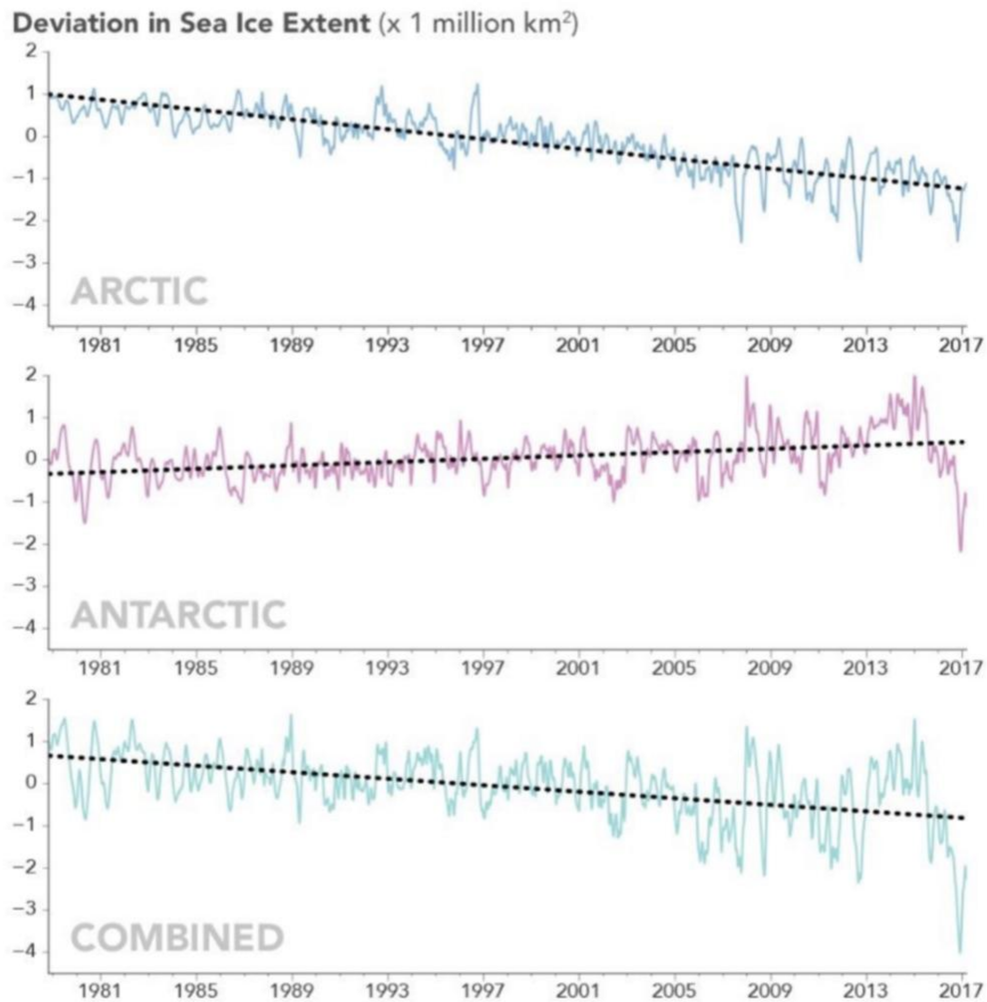
Changing geographic distribution of Malaria with Global Warming:
https://ngss.nsta.org/Resource.aspx?ResourceID=650

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.

Watch the video below. Review the graphs provided by NASA on Deviation in Sea Ice Extent. Answer the questions below.

Arctic Sea Ice Reaches Another Record Low



These line graphs plot monthly deviations and overall trends in polar sea ice from 1979 to 2017 as measured by satellites. The top line shows the Arctic; the middle shows Antarctica; and the third shows the global, combined total. The graphs depict how much the sea ice concentration moved above or below the long-term average. (They do not plot total sea ice concentration.) Arctic and global sea ice totals have moved consistently downward over 38 years. Antarctic trends are more muddled, but they do not offset the great losses in the Arctic.

Credits: Joshua Stevens/NASA Earth Observatory

https://www.nasa.gov/feature/goddard/2017/sea-ice-extent-sinks-to-record-lows-at-both-poles

1. Explain how both the cryosphere and hydrosphere systems are affected by citing evidence from the video and graphs.

2. Two students are debating after watching the video and reviewing the graphs. Student One claims that if the Larsen C ice sheet melts it will result in sea level rise. Student Two disagrees. Which student's claim is best supported by the video and graphs? Why?

3. Predict how an increase in human caused global warming would affect continental ice sheets in Greenland. Describe one impact on either the hydrosphere, cryosphere or biosphere.

HS-ESS3-6 Assessment - Larsen C Ice Sheet

Universal Supports	Targeted Supports

• Model computational representations related to the various Earth systems
• Exploration of the various spheres (hydrosphere, geosphere, atmosphere, cryosphere, biosphere) - allow student choice of resources to explore and ways for students to use the information available
• Before conducting small group activity, make sure that all students understand the expectations, instructions, and their role in the performance of the task. The teacher may check for understanding by asking questions regarding the expectations and how to complete the task.
• Use turn-taking strategies, timer, and model meaningful participation to avoid "knower" or a few students dominating the conversation.
• *S*et protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing. Involve students in setting these protocols and ground rules.
• Students will likely need additional support with:
  ○ Math concepts - Use clarifying questions to determine misunderstandings
  ○ Interactions among the spheres - use analogies and real-life examples
  ○ Human impact - use analogies and real-life examples
	• Provide targeted individualized interventions
	• Provide examples and scaffold for students in the following areas as need arises:
	  ○ Give a step-by-step instructions and have students repeat them
	  ○ Provide an anchor chart on how to do the calculations such as percentage and proportions
	  ○ Walk students through the mathematical computation
	  ○ Give more space to write problems and solutions.
	  ○ Provide calculators if computation is not being assessed

Common Misconceptions

- Each sphere acts independently - no interactions
- Natural systems continue unchanged by human activity
- Solutions to human impacts on the environment have already been developed and implemented
- Interactions between human activity and Earth systems are always negative.
- Interactions between human activity and Earth's systems involve a single sequence of causes and effects rather than a complex system in which multiple interactions happen simultaneously.
- Changes to Earth systems will not affect people.
- The effects of human activities on Earth systems can only be felt in the long term.

Source: California Department of Education

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- What do you believe about the interactions among the biosphere, atmosphere, hydrosphere, cryosphere, and geosphere? How do we as humans affect these systems?
- What do you believe about the relationship between humans and the natural world? Allow all students to share their beliefs.
- How can we assist those from other cultural backgrounds in understanding the role of humans on the earth systems?
- Native cultures and Mexican American cultures both have a strong connection to the natural world that emphasize symbiosis rather than use or domination. Emphasize how well this attitude aligns with this PE and conservation in general. Assist non-native/Mexican students in seeing the value of these cultural beliefs.

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.