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New Mexico STEM Ready! Science Standards Implementation Guide

Overview

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

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

The standards

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

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

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

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

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[1] Pratt, Harold (2013) *The NSTA 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

[Earth's Systems]
[HS-ESS2-1]
[HS-ESS2-2]
[HS-ESS2-3]
[HS-ESS2-4]
[HS-ESS2-5]
[HS-ESS2-6]
[HS-ESS2-7]

Students who demonstrate understanding can:

HS-ESS2-1. **Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [*Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS2.A: Earth Materials and Systems** • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. *(ESS2.B Grade 8 GBE)*	**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.PS2.B

Articulation of DCIs across grade-bands:
MS.PS2.B ; **MS.LS2.B** ; **MS.ESS1.C** ; **MS.ESS2.A** ; **MS.ESS2.B** ; **MS.ESS2.C** ; **MS.ESS2.D**

Common Core State Standards Connections:

ELA/Literacy -

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-ESS2-1)*

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-ESS2-1)
MP.4 Model with mathematics. (HS-ESS2-1)
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-ESS2-1)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-1)
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-1)

Grade	NGSS Discipline
HS	**Earth and Space Science 2.1**
ESS2-1	**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.

Introduce and show the different landscape and landforms in the southwest United States in the form of a video or pictures. Below is an introduction/description that can be used as a brief textual background.
Claim-Evidence-Reasoning model can be used for students to answer this question:

Images: sciencing.com

Britannica.com

Above: Wildflowers decorate the Organ Mountains, near Las Cruces. Photograph by Wayne Suggs.

Nature.org

Video Resources:
- Remembered Earth - New Mexico's High Desert
- New Mexico by Drone (4K)

Question:
- In relation to the internal processes that occur on earth, what brought these different landforms in the southwest? How is it different from other parts of the world?

A student or a group of students can focus on a specific land feature.

Spectacular Landscapes of the Southwest U.S.

The Southwest United States consists of four states: Arizona, New Mexico, Texas, Oklahoma. In relation to the rest of the world, the Southwest is located in the Western Hemisphere in North America.
From towering peaks to deep basins, the southwestern region of the United States is home to a colorful assortment of distinctive landforms. The most prominent landform in the Southwest is the Rocky Mountains. Other important landforms are the Coastal Plain--a low, flat area bordering the Gulf of Mexico--and the Great Plains--a low, flat, wheat-growing area, which runs all the way up into Canada. West of the Rocky Mountains is the Colorado Plateau, which covers much of northern New Mexico and Arizona. The Colorado Plateau takes its name from the Colorado River, which runs through it.

Nat Geo video: Time-Lapse: Spectacular Landscapes of the Southwest U.S. | National Geographic

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 scatter plots 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.*

Task Components

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 scatter plot is more accurate or easier to calculate. Using your scatter plots 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 scatter plots 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 images and videos to give key background information about different land features such as mountains, valleys, and plateaus, and sea-floor features such as trenches, ridges, and seamounts.
- Utilize anchor charts to explain concepts
- Provide students with guided questions and sentence stems
- Create a protocol for sharing out in small groups and whole group
    - Assign specific land and sea floor features to groups
- Utilize READ, TALK, WRITE strategy
    - Have students highlight or underline words that they do not understand and words that sparks their interest or that they are very familiar with.
        - As you facilitate the activity, provide scaffold and explicit instructions to clarify vocabulary words or tasks.
    - Have students share in groups the words or statements from the reading article that sparks their interest. Affirm students statements and find means how their statements relate to others.
- Complete a gallery walk with students observing constructive forces and destructive mechanisms
- Use turn-taking strategies, timer, and model meaningful participation to avoid “knower” or a few students dominating the conversation.
- If students are experts or interested in certain aspects of the activity or concepts being presented in the activity, assign these students to become the resource person for their area of expertise or interest. Assign these students to become the resource person for their area of expertise or interest. Refer students to them if they have questions about the task that relates to the resource person’s expertise or interest.

- Utilize targeted small group instruction to address student misconceptions
- Provide different anchor charts and complete them one-on-one with students

Common Misconceptions

- Human activities cannot affect geological processes like river floods and mass wasting.
- Glaciers are only moving ice masses (with little to no concept of sediment transport).

- Glacial ice moves backward during glacial 'retreats.'
- Glacial ice is stationary during times when the weather front is neither advancing or retreating.

Source: Introduction to Erosion This unit contains resources about the three agents of erosion

- Clark and Libarkin (2011) found students confuse spreading ridges with hot spots and are unable to identify the directional motion of boundaries without arrows. Melting occurs at great depths due to high temperatures rather than changes in pressure or chemistry. Sibley (2005) finds students do not conceptualize crustal thickening at continent-continent margins. King (2000) and others find students overestimate the thickness of the crust.
- Barrow and Haskins (1996) and Parham et al. (2010) report earthquakes and volcanoes most likely to happen at continental coastlines and in warm equatorial regions. Libarkin et al. (2005b) found students rarely connect volcanoes and earthquakes to plate tectonics.
- Libarkin and Anderson (2005a) report students think Earth's hot interior is due to insufficient cooling rather than energy from radioactive decay.
- Students don't identify the crust under oceans, just continents.
- Students think melting is due to high temperature rather than pressure.

Source: Geology misconceptions targeted by an overlapping consensus of US national standards and frameworks

- Volcanoes only form at plate boundaries.
- All valleys are the result of downcutting by rivers.
- Internal and surface processes operate on the same spatial and temporal scale.

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

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- 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.
- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- Incorporate short breaks in between activities and have students from different cultural backgrounds share their customary ways of doing brain breaks and physical movements to relax their mind and body.
- If available, look for curriculum or activities from local, cultural, and sociopolitical organizations that can help deliver the content for this standard.
- If students will be required to present their work/project/assignment, allow and encourage students to present in the modality of their choice and, if possible, incorporate their culture and language.
- Use videos or articles that are representative of all cultural groups in your classroom.
- Set 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.
- Invite guest speakers and experts from the local community or specific minorities to talk about the topic. In addition, encourage students to ask questions to the guest speaker regarding any concept that they do not understand and that needs clarification and affirmation.

Students who demonstrate understanding can:

HS-ESS2-2. **Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

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 tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	**ESS2.A: Earth Materials and Systems** • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.D: Weather and Climate** • The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.	**Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Connections to other DCIs in this grade-band:
HS.PS3.B ; **HS.PS4.B** ; **HS.LS2.B** ; **HS.LS2.C** ; **HS.LS4.D** ; **HS.ESS3.C** ; **HS.ESS3.D**

Articulation of DCIs across grade-bands:
MS.PS3.D ; **MS.PS4.B** ; **MS.LS2.B** ; **MS.LS2.C** ; **MS.LS4.C** ; **MS.ESS2.A** ; **MS.ESS2.B** ; **MS.ESS2.C** ; **MS.ESS2.D** ; **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-ESS2-2)*

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-ESS2-2)*

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-ESS2-2)

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS2-2)

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-2)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 2.2**
ESS2-2	**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.* **Directions:** Have students read the news article below. Lake Mead declines to new low as Colorado River crisis deepens The shocking numbers behind the Lake Mead drought crisis **Video Resource:** Lake Mead's low water level prompts feds to consider declaration of Colorado River water shortage

Ask: What brought Lake Mead to its current situation? What are the different factors that brought this change? Assign students to do research and gather data about the historical water level of the Colorado River particularly Lake Mead, and the different factors that brought this change. Focus their investigation on human activities linked to the changes in the water level of Lake Mead. The Claim-Evidence-Reasoning model can also be used for students to answer this question.

Lake Mead's low water level prompts feds to consider declaration of Colorado River water shortage

Lake Mead's low water level prompts feds to consider declaration of Colorado River water shortage The nation's largest reservoir is at only 37% of its capacity. That water flows downstream to customers in Nevada, Arizona and California, all of which face potential delivery cutbacks. The punishing mega drought, as scientists call it, brought by climate change grips much of the Western US. The latest US drought monitor map shows large areas of the Southwest are exceptionally dry. The worst category is taking a dramatic toll on the Colorado River system that provides water to 40 million people in seven different states. For the first time ever, the federal government is expected to declare a water shortage on the lower Colorado River later this summer. That will force automatic cuts to the water supply for Nevada and Arizona starting in 2022. Homeowners have higher priority and at first will not feel the pain as badly as farmers. Pat Mulroy, the former head of the Southern Nevada Water Authority, says a rapidly retreating reservoir may be the new normal. And the millions of people who rely on this water supply will have to quickly learn to live with less of it.

Source:
https://news.yahoo.com/lake-mead-low-water-level-123637494.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAHRI-p0LzRv0FqzuwsNsBnx-7gEZNQ-zz5d-p0oJ11VOg0qfUrNkSqzOe_mgmW_Mw6_BXZE0fCZlRKJbeWDJ-1X9ZF9m-https://www.azcentral.com/story/news/local/arizona-environment/2021/06/10/lake-mead-declines-new-low-colorado-river-crisis-deepens-arizona-drought/7621138002/YgOWB_hFTg9wquc81C-FaI1sFMcphFCLGP8p6fVVbcJSu1SSKrxfzqnjt7KAKkSe96aePKGdoe60pWL

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.

Figure 1 News article: Biocarbon Engineering's tree-planting drones are flying in Myanmar

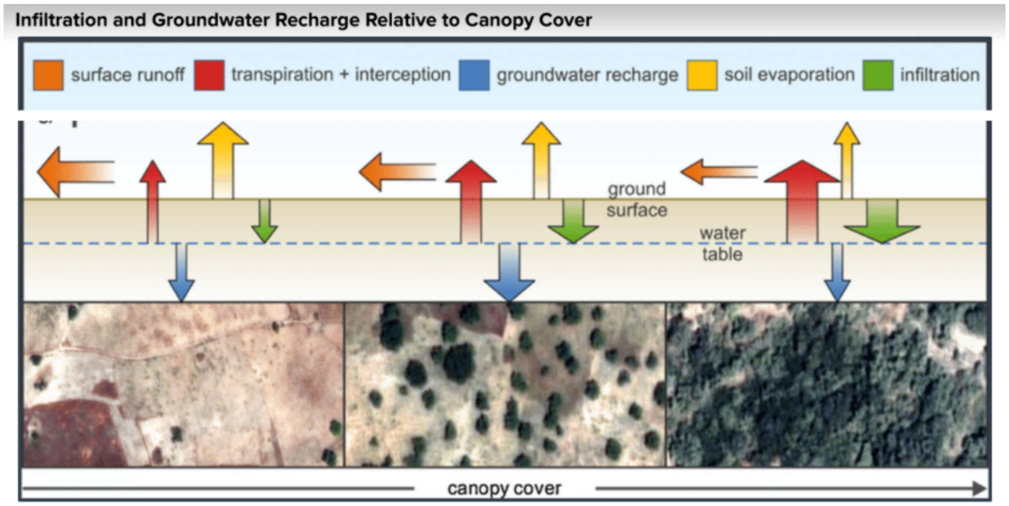


Figure 2. Infiltration and groundwater recharge relative to canopy cover. Source: adapted from (Ilstedt et al., 2016). The relationship between tree cover and groundwater recharge. Arrows depict the conceptual water budget based on the optimum tree cover theory. ***The size of the arrows is proportional to the magnitude of each component of the water budget.***

Ellison, et al. (2017). Trees, forests and water: Cool insights for a hot world. Global Environmental Change. 43. 51 61. 10.1016/j.gloenvcha.2017.01.002.

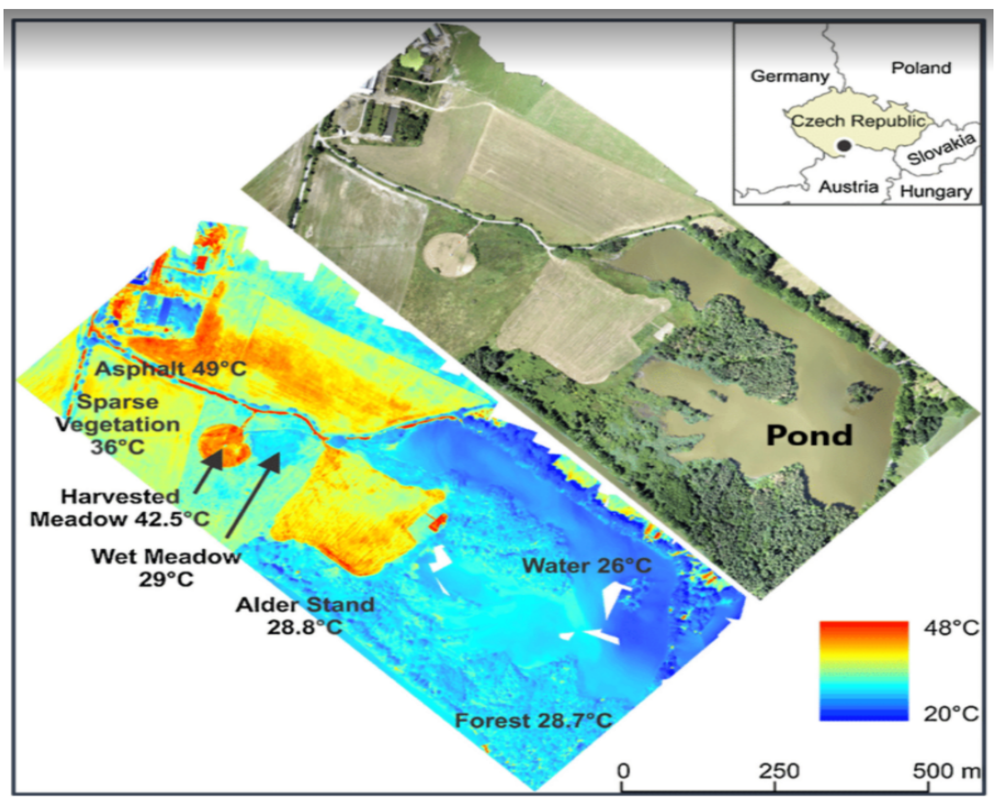


Figure 3. Surface temperature distribution in a mixed landscape with forest. Source: adapted from (Hesslerová et al. 2013).

1. Organize the data from the graph into the following graphic organizer. Use words like: the most, the greatest, the least, high, low, medium

Canopy Cover	**No canopy cover**	**Some canopy cover**	**Full canopy cover**
Surface Runoff			
Transpiration			
Groundwater recharge			
Soil evaporation			
Infiltration			
Temperature			

2. Identify how the patterns you identified for each variable would affect each of the following storages. Use words like: increase, decrease, no change. Then, describe the mechanism or process that would result in those changes.

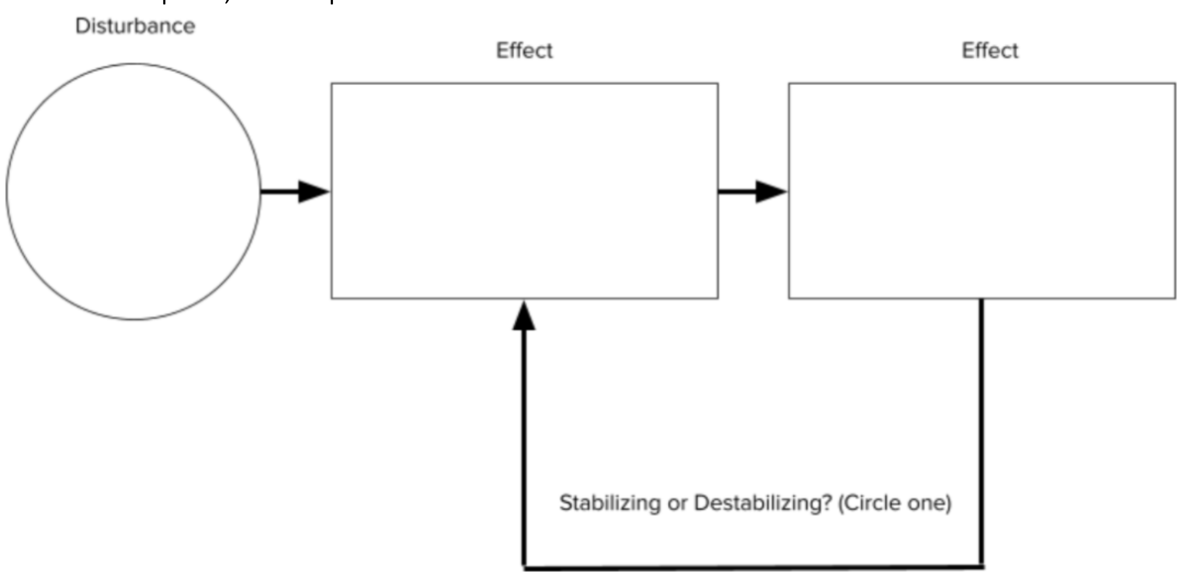
Cause	Mechanisms (Describe the process that connects the cause & effect)	Effect on Water Storage in
Increase in Canopy Cover		Soil
		Atmosphere
		Groundwater

3. When humans clear an area of forest to expand farmland, what are some of the effects to the local habitat besides the loss of canopy cover?

4. Identify examples of human actions that could affect canopy cover.

Cause: Human Action	Effect
	Increase canopy cover
	Decrease canopy cover

5. Create a model to show how a specified change in canopy cover could result in a feedback loop that affects another Earth system. Keep in mind, Earth systems include the geosphere, cryosphere, hydrosphere, atmosphere, and biosphere.



6. Identify if the feedback in the system above is stabilizing or destabilizing. Explain your reasoning.

7. A group of ecologists wants to use drones in a reforestation project. The drones will locate abandoned fields and plant tree seeds in nutrient balls. The project's aim is to increase biodiversity in the region. What is one potentially unanticipated effect on two of Earth's systems based on the data you have analyzed?

8. Figure 2 has representations of the magnitude of each component of the water budget in the study site.
    a. What are the limitations of this model?
    b. How could the model's accuracy be improved?

9. The data shown in Figure 2 came from three years of investigations in Burkina Faso, western Africa. Evaluate the uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation, etc.) that may have affected the interpretation of the data.

Source Link: [HS-ESS2-2 Assessment - Reforestation's Effects on Earth System]

Universal Supports	Targeted Supports
• Utilize a KWL chart to understand student's knowledge and misconceptions of climate change and global warming • Create a driving question board to keep track of and revisit student's questions about global warming • Provide sentence stems for students • Provide questions that the students can think about and answer as they watch the videos • Provide students with clear expectations, instructions, and their role in the performance of the task. • Use turn-taking strategies, timer, and model meaningful participation to avoid "knower" or a few students dominating the conversation. • Set 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.	• Utilize targeted small group instruction to address student misconceptions • Provide partially completed graphic organizers

Common Misconceptions

- The atmosphere, hydrosphere, lithosphere, and biosphere do not cause changes in one another; these systems operate independently on Earth.
- All bedrock is solid, nonporous material.
- Human activities cannot affect geological processes like river floods and mass wasting.
- The greenhouse effect/greenhouse gases are always bad.
- Earth is primarily warmed directly by sunlight (real-life experience, walk into the sunlight you get warm, it is difficult to disassociate sunlight from the 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).

- Climate change is only caused by human activities.
- Short-term anomalies in data are evidence for or against long-term trends.
- Small changes in Earth's systems have no significant long-term effects.

Sources:

- https://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html
- https://teachearthscience.org/erosion.html
- https://www.cde.ca.gov/

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- Incorporate short breaks in between activities and have students from different cultural backgrounds share their customary ways of doing brain breaks and physical movements to relax their mind and body.
- Look for curriculum or activities from local, cultural, and sociopolitical organizations that can help deliver the content for this standard.
- If students will be required to present their work/project/assignment, allow and encourage students to present in the modality of their choice and, if possible, incorporate their culture and language.
- Use videos or articles that are representative of all cultural groups in your classroom.
- Allow students to share in class the words or statements from the reading article that sparks their interest. Affirm students statements and find means how their statements relate to others.
- If students are experts or interested in certain aspects of the activity or concepts being presented in the activity, assign these students to become the resource person for their area of expertise or interest. Refer students to them if they have questions about the task that relates to the resource person's expertise or interest.
- If time permits and reinforcement is needed, invite guest speakers and experts from the local community or specific minorities to talk about the topic. In addition, encourage students to ask questions to the guest speaker regarding any concept that they do not understand and that needs clarification and affirmation.
- For sources of information and data that the students can use, see if there are local organizations and websites that can be provided to the students where they can get the most recent data tied to the culture and community.
- Be sensitive to ethnocentric views of different cultures regarding climate change. In discussing this topic, make sure to not nurture fear and intolerance so that the threats of climate change will not propagate social conflict.

Students who demonstrate understanding can:

HS-ESS2-3. **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

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

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science knowledge is based on empirical evidence.
- Science disciplines share common rules of evidence used to evaluate explanations about natural systems.
- Science includes the process of coordinating patterns of evidence with current theory.

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

ESS2.B: Plate Tectonics and Large-Scale System Interactions
- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

PS4.A: Wave Properties
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary to HS-ESS2-3)

Crosscutting Concepts

Energy and Matter
- Energy drives the cycling of matter within and between systems.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.

Connections to other DCIs in this grade-band:
HS.PS2.B ; **HS.PS3.B** ; **HS.PS3.D**

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.PS2.B** ; **MS.PS3.A** ; **MS.PS3.B** ; **MS.ESS2.A** ; **MS.ESS2.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-ESS2-3)*
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-ESS2-3)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS2-3)
MP.4	Model with mathematics. (HS-ESS2-3)
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-ESS2-3)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-3)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-3)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 2.3**
ESS2-3	**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.

Volcanoes, Earthquake, and Plate tectonics

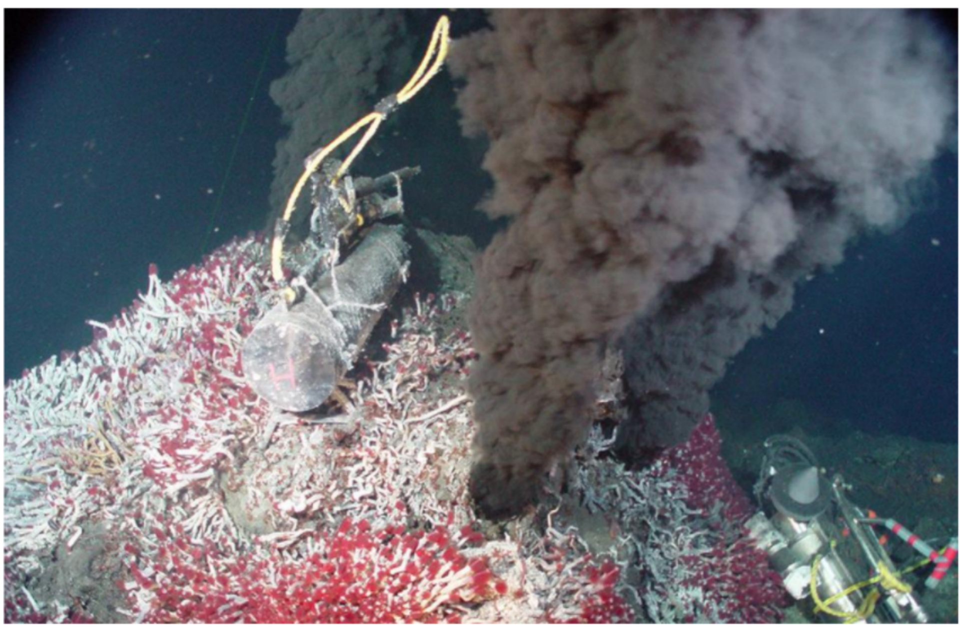
Descriptions: Begin by showing students a short video clip of a recent volcanic eruption (example: Kilauea Volcano Eruption | A Perfect Planet | BBC Earth). Then, provide students with an interactive map of volcanoes in the world. Use the interactive map for students to map volcanoes of the world and identify patterns in terms of their location. Provide additional maps such as plate tectonic maps and latest earthquake maps. Have students investigate patterns and relationships among the three maps. Have students formulate claims on what creates volcanic eruptions and earthquakes and why they are common along plate boundaries. Then, make students develop a model that will support their claim.

Interactive Map of Active Volcanoes: Interactive Map of Active Volcanoes and recent Earthquakes world-wide
Plate Tectonics Map: Plate Tectonics Map - Plate Boundary Map
Latest Earthquake Map: Latest Earthquakes

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.

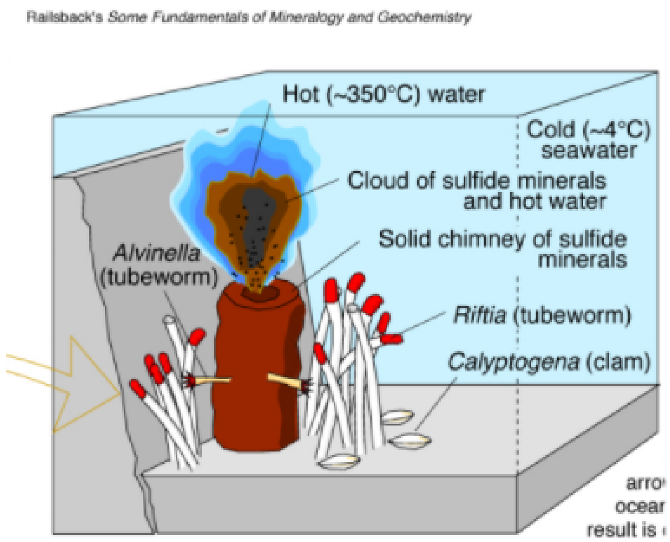
What is a hydrothermal vent? Video Link: Hydrothermal Vents: 2016 Deepwater Exploration of the Marianas



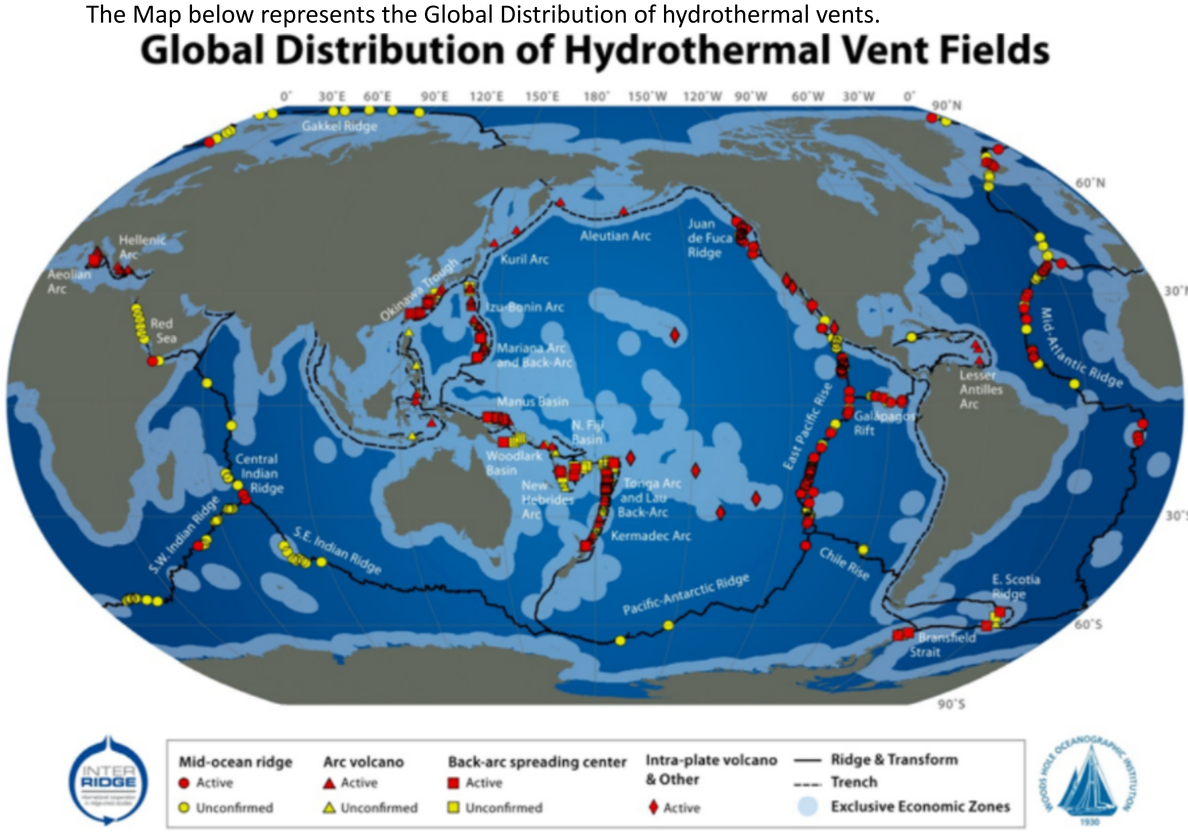
A venting black smoker emits jets of particle-laden fluids. The particles are predominantly very fine-grained sulfide minerals formed when the hot hydrothermal fluids mix with near-freezing seawater. These minerals solidify as they cool, forming chimney-like structures. “Black smokers” are chimneys formed from deposits of iron sulfide, which is black. “White smokers” are chimneys formed from deposits of barium, calcium, and silicon, which are white.

Scientists first discovered hydrothermal vents in 1977 while exploring an oceanic spreading ridge near the Galapagos Islands. To their amazement, the scientists also found that the hydrothermal vents were surrounded by large numbers of organisms that had never been seen before. These biological communities depend upon chemical processes that result from the interaction of seawater and hot magma associated with underwater volcanoes. Modified From NOAA Vent Facts - https://oceanservice.noaa.gov/facts/vents.html

Biologic Model of Vent Organisms:



The Map below represents the Global Distribution of hydrothermal vents.



a. What other geologic features are associated with these vents?
b. Based on your understanding of the Earth's interior, how are the features described related to the location of hydrothermal vents?

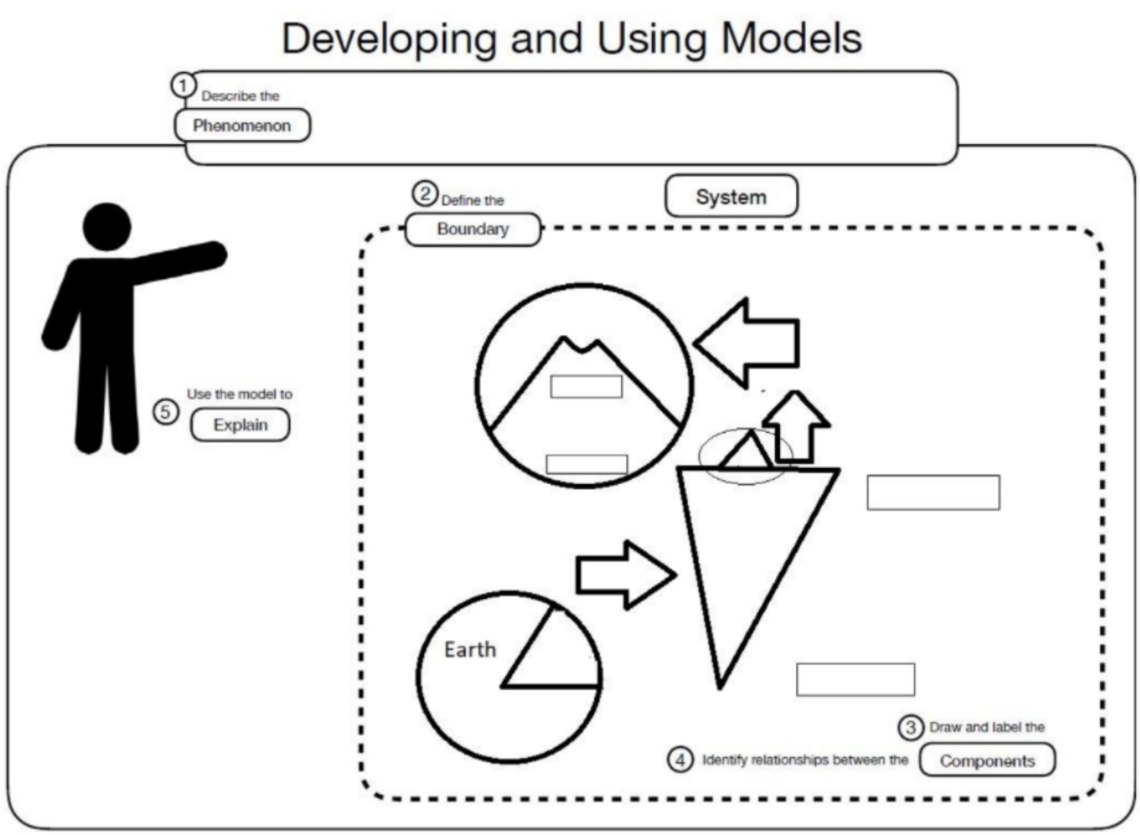
2. Given this information correctly organise the following order of events related to the flow of energy in this system.

A.New Crust Formed and cooled
B.Convection in Earth's Upper Mantle
C.Energy from Earth's Formation
D.Radioactive Decay of Isotopes
E.Heat From vent Fueling Chemical Processes in living things

____________ → ______________ → _____________ → _____________ → __________

3. Develop a Model using the attached diagram based on your understanding of the Earth's Interior, demonstrating your understanding of Earth's layers, density gradients, cycling of matter and direction of plate movement at hydrothermal vents.

Possible differentiated Model Option for additional scaffolding:



Source Link:

[HS-ESS2-3 Assessment - What is a hydrothermal vent? (NY)]

Universal Supports

- Provide an anchor chart for students to complete with information about the earth's different interior layers (composition, thickness, density, pressure, temperature, etc).
- Provide a reliable source of information where they can gather this information (can be a physical copy of a text or a website).
- Provide a time frame for students and have them fill in the information within the allotted time.
- Provide sentence stems to allow students to reflect on how the different layers are related (similarities, differences, connections, etc).
- **Give One, Get One, Move On**
    - Create a GoGoMo chart that has the different layers of the earth's interior.
    - Have students stand up, pair up, and solicit statements that their classmate wrote related to any of the specified layers. Students exchange their paper GoGoMo charts and write on each other's charts.

Lithosp here	Upper Mantle	Lower Mantle	Outer Core	Inner Core

Targeted Supports

- Individualized targeted instruction
- Provide video resources to reinforce content for struggling students and have individual discussions to provide in depth explanations and address misconceptions
    - [A guide to the energy of the Earth - Joshua M. Sneideman]
    - [Earth's Delicate Energy Balance | California Academy of Sciences]

Common Misconceptions

- Crust and Lithosphere (or plates) are synonymous terms
- The asthenosphere is liquid (students are only familiar with liquid convection, not solid convection, many secondary education earth science films also specifically refer to a molten internal layer, and some

fundamentalist religious groups specifically refer to the existence of a molten layer that is hell's physical location).
- Lower Mantle is liquid (for reasons similar to above).
- Earth's core is hollow, or that large hollow spaces occur deep within Earth (a relict of older cosmology and a mainstay of popular literature and Hollywood movies)
- Only continents move (Wegener's original concept, along with the common use of 'Continental Drift' term in general texts, secondary education earth science films, etc.)
- Most crust motions (especially those associated with processes of mountain building or deep-sea trench formation) are due to vertical motions, not lateral (terms like 'mountain uplift' and earth science textbook terminology, as well as a relict idea from old cosmologies).
- Divergent ocean ridges are due to vertical uplift or convergence, rather than divergence (In students' experience, buckling is usually due to convergence or uplift, not heat/density differences, so illustrations of ridges do not readily fit with a pulling apart motion).
- Present oceans only began as Pangea broke apart - tied to the general idea that Pangea was the original continent at the Earth's start (few educational earth science films mention what came before Pangea & emphasis on Atlantic spreading leads to Pacific being overlooked).
- Plate movement is imperceptible on a human timeframe (common use of fingernail growth analogy is only true for slowest plates and underestimates the importance of motion).
- Plate motion is rapid enough that continental collision can cause financial and political chaos while rifting can divide families or separate a species from its food source.
- Oceans are responsible for the oceanic crust (rather than being closer to another way around).
- Continental 'shelves' are similar to shelves in homes, extend out over the edge of the continent and can break and collapse to form tsunamis (so Boxing Day tsunami was due to shelf collapse)
- The edge of a continent is the same thing as a plate boundary.
- Over time there has been no significant change in the ratio of oceanic to continental areas (the idea of stasis is a common misconception, but this was also part of Lyell's original concept).
- Apart from differences due to changes in ice volume, sea level has remained relatively constant through time (recognition of the impact of plate speed on sea level not even recognized by geologists until relatively recently).
- A plate boundary type is the same thing as a plate. For example, a plate has to be divergent or convergent.
- Tectonic plates float and move above a sea of magma.
- Plates are deep beneath Earth's surface.
- Magma originates from the core.
- Convection only occurs in liquids.
- Radioactivity is man-made.

Source: https://www.cde.ca.gov/
Source: https://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- Incorporate short breaks in between activities and have students from different cultural backgrounds share their customary ways of doing brain breaks and physical movements to relax their mind and body.
- If available, look for curriculum or activities from local, cultural, and sociopolitical organizations that can help deliver the content for this standard.

	• If students will be required to present their work/project/assignment, allow and encourage students to present in the modality of their choice and, if possible, incorporate their culture and language.
	• Use videos or articles that are representative of all cultural groups in your classroom.
	• If students are experts or interested in certain aspects of the activity or concepts being presented in the activity, assign these students to become the resource person for their area of expertise or interest. Refer students to them if they have questions about the task that relates to the resource person's expertise or interest.
	• If time permits and reinforcement is needed, invite guest speakers and experts from the local community or specific minorities to talk about the topic. In addition, encourage students to ask questions to the guest speaker regarding any concept that they do not understand and that needs clarification and affirmation.
	• In using the phenomena, particularly on showing a short video clip of a recent volcanic eruption, the teacher may begin by asking students:
	  ○ What do you know about volcanoes?
	  ○ Have you seen a volcano?
	  ○ Do you have cultural or religious beliefs that relate to volcanic eruption or activity?

Students who demonstrate understanding can:

HS-ESS2-4. **Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [*Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.*]

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

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
- Use a model to provide mechanistic accounts of phenomena.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

Disciplinary Core Ideas

ESS1.B: Earth and the Solar System
- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(secondary)*

ESS2.A: Earth Materials and Systems
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate
- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

Crosscutting Concepts

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

Connections to other DCIs in this grade-band:
HS.PS3.A ; **HS.PS3.B** ; **HS.LS2.C** ; **HS.ESS1.C** ; **HS.ESS3.C** ; **HS.ESS3.D**

Articulation of DCIs across grade-bands:
MS.PS3.A ; **MS.PS3.B** ; **MS.PS3.D** ; **MS.PS4.B** ; **MS.LS1.C** ; **MS.LS2.B** ; **MS.LS2.C** ; **MS.ESS2.A** ; **MS.ESS2.B** ; **MS.ESS2.C** ; **MS.ESS2.D** ; **MS.ESS3.C** ; **MS.ESS3.D**

Common Core State Standards Connections:

ELA/Literacy -
SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-ESS2-4)*

Mathematics -
MP.2 Reason abstractly and quantitatively. (HS-ESS2-4)
MP.4 Model with mathematics. (HS-ESS2-4)
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-ESS2-4)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-4)
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-4)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 2.4**
ESS2-4	**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.*

Description:
Provide reading articles about the climate crisis and how it affects certain regions. A sample article is provided below. Lead the discussion towards climate in New Mexico and factors that affect it. One of the factors that may be brought by students are greenhouse gases. Then, have students think how the increased greenhouse effect causes global warming and what brings greenhouse gases.

New Mexico, the Land of Enchantment, is impacted by climate crisis in three ways:

- **HEAT**
- **WATER SECURITY AND DROUGHT**
- **WILDFIRE**

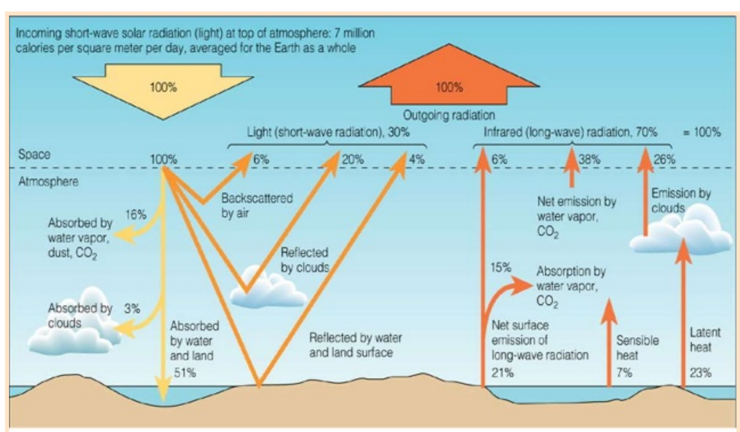
Source: How Is the Climate Crisis Affecting New Mexico?
YouTube video: Climate Change Threatens New Mexico Water, Land Resources

Classroom Assessment Items

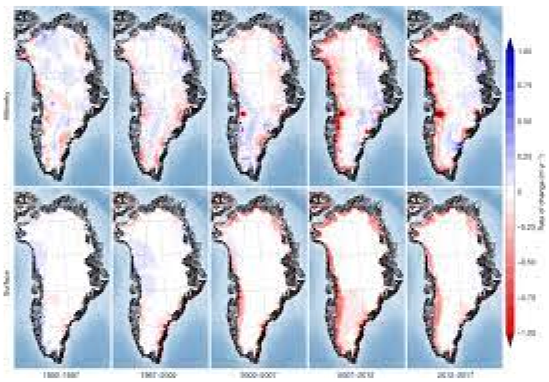
When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

Where have all the glaciers gone?

Introduction: 11 billion tons of ice melted in Greenland in just one day. This change will affect the global climate. Let's start by looking at Earth's Heat Budget to see how energy moves throughout Earth . This model shows the heat budget of Earth, on an average day. Notice that there is an overall balance between the energy input and output.



Below are several pictures of Greenland over time. Examine the pictures to see what changes have occurred.



www.Nature.com

Image source: www.nationalgeographic.com
Researchers look at meltwater at the edge of the Greenland ice sheet.
PHOTOGRAPH BY GINNY CATANIA, NAT GEO IMAGE COLLECTION

Summation of Assessment
11 billion tons of ice melted in Greenland in one day

Greenland is seeing midsummer melting of snow and ice. Greenhouse gases have raised the temperatures in the arctic. The melting of ice and the darkening of Greenland have resulted in increased temperatures. The loss of ice and snow allows more heat to be absorbed. Changing the ice changes the pattern of the whole climate in Greenland.

Greenland Surface Conditions

1. Using the graphic organizer below, identify and describe one component that will effect the energy input and output of Earth's energy system.

Cause	Factors	Increase/Decrease Energy	How/Why the factor affects Earth's System
Input			
Output			
Storage			

2. State the relationship between the components of this energy system and the heat budget.
3. Is this relationship causal or correlational? Explain.
4. How do changes in Earth's spheres effect the energy flowing into and out of Earth systems?

Universal Supports	Targeted Supports
● Provide graphic organizers to help student organize their thoughts ● Provide model examples to groups and have them describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. ● Set 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. ● Utilize images, an animation, or interactive tracing the pathway of energy on earth. ○ Here is an application that can be installed in student device and can be used: TERC EarthLabs on the App Store ● Set clear time limits for groups to brainstorm and plan identifying and describing the relationships, either causal or correlational, between components of their assigned	● Individualized targeted instruction ● Provide video resources to reinforce content for struggling students and have individual discussions to provide in depth explanations and address misconceptions ○ A guide to the energy of the Earth - Joshua M. Sneideman ○ Earth's Delicate Energy Balance | California Academy of Sciences

model/interactive, and organize the factors from the given model into three groups:
  - Those that affect the input of energy;
  - Those that affect the output of energy; and
  - Those that affect the storage and redistribution of energy
- Provide students with various options to follow the energy flow on earth.
  - Create discussion protocols to do a brief discussion of where we get our energy and what drives the climate on earth.
    - Lead the discussion towards solar power driving Earth's climate and providing us with the energy.
    - Provide sentence stems for students to participate in the discussion
  - Show a short video clip about the key role of the sun in driving earth's climate. Here's a sample: How Much Does the Sun Affect Earth's Climate?
    - Provide students with discussion questions
  - Do a quick collaborative work with the following prompt: Write down different ways the sun affects us directly and indirectly. Provide an example. You may use a strategy called "Give One, Get One, Move on (GoGoMo)"

Common Misconceptions

- The equator is warmer because the tropics are closer to the Sun. (older cosmology dating to Icarus myth, depictions in earth science textbooks, real-life experiences with heat source
- Earth's climate is controlled primarily by the atmosphere circulation, rather than ocean circulation (real-life experiences as a terrestrial animal, TV weather reports)
- Earth's orbit is constant.
- Earth is always the same distance from the Sun.
- El Niño and La Niña events only affect equatorial regions.
- Removal of greenhouse gases from the atmosphere is easy to accomplish.

Source: https://www.cde.ca.gov/
Source: https://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- If available, look for curriculum or activities from local, cultural, and sociopolitical organizations that can help deliver the content for this standard.
- If students will be required to present their work/project/assignment, allow and encourage students to present in the modality of their choice and, if possible, incorporate their culture and language.
- Use videos or articles that are representative of all cultural groups in your classroom.
- If students are experts or interested in certain aspects of the activity or concepts being presented in the activity, assign these students to become the resource person for their area of expertise or interest. Refer students to them if they have questions about the task that relates to the resource person's expertise or interest.
- If time permits and reinforcement is needed, invite guest speakers and experts from the local community or specific minorities to talk about the topic. In addition, encourage students to ask questions to the guest speaker regarding any concept that they do not understand and that needs clarification and affirmation.
- Be sensitive to ethnocentric views of different cultures regarding climate change and/or natural calamities such as volcanic eruption. In discussing this topic, make sure to not nurture fear and intolerance so that the threats of climate change and natural calamities will not propagate social conflict.
- When the "sun" is derived from students' responses, briefly talk about their cultural views about the sun. Have students from different backgrounds share their cultural and/or religious beliefs about the sun. The teacher may also ask students to share to the class the term for the sun in their local language or dialect.
- These questions can be asked to students when climate change is brought up in the conversation:
    - What do you believe about climate change?
    - Why do you believe as you do? What factors have influenced your beliefs?
    - What do you believe about the role of humans in addressing climate change?
    - What is your cultural view and/or personal view on why we should play a role in addressing climate change?

Students who demonstrate understanding can:

HS-ESS2-5. **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.	**Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Connections to other DCIs in this grade-band:
HS.PS1.A ; **HS.PS1.B** ; **HS.PS3.B** ; **HS.ESS3.C**

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS4.B** ; **MS.ESS2.A** ; **MS.ESS2.C** ; **MS.ESS2.D**

Common Core State Standards Connections:
ELA/Literacy -
WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ESS2-5)
Mathematics -
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-5)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 2.5**
ESS2-5	**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.* **How has the Grand Canyon Formed?** The Grand Canyon is a landform that was carved by the Colorado River over millions of years through weathering and erosion. Even though the work of the Colorado took millions of years this is relatively rapid compared to the billions of years of deposition revealed by the Canyon. A trip down into the Grand Canyon is literally a trip back in time written in the rocks. Video Resource: How has the Grand Canyon Formed?

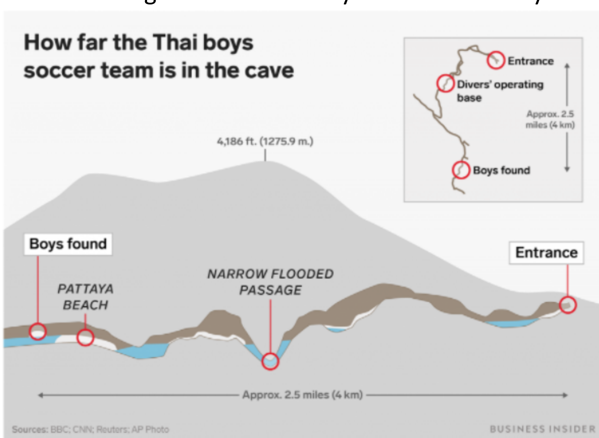
Web Resources: Grand Canyon National Park, Grand Canyon - Wikipedia, Grand Canyon: Location, Formation & Facts - LiveScience

Classroom Assessment Items

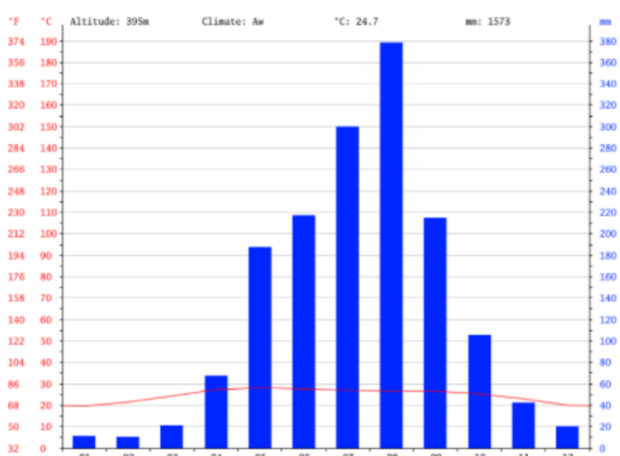
When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

Watch the CNN report video: [Rescuers up against 'water and time' to save remaining teammates trapped in Thai cave]

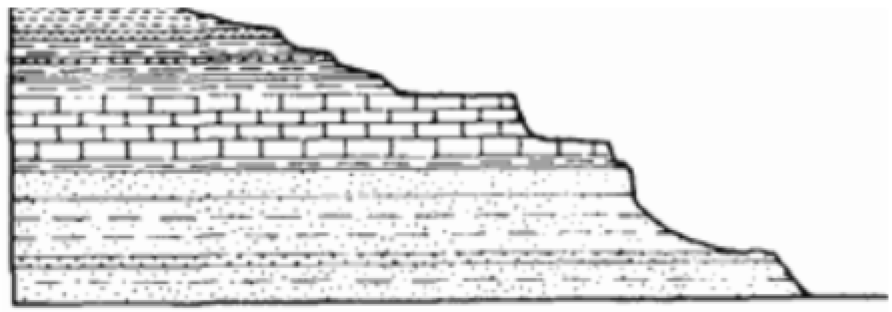
Below is a diagram of the cave system that the boys were trapped in.



Below is a climograph of the cave location.

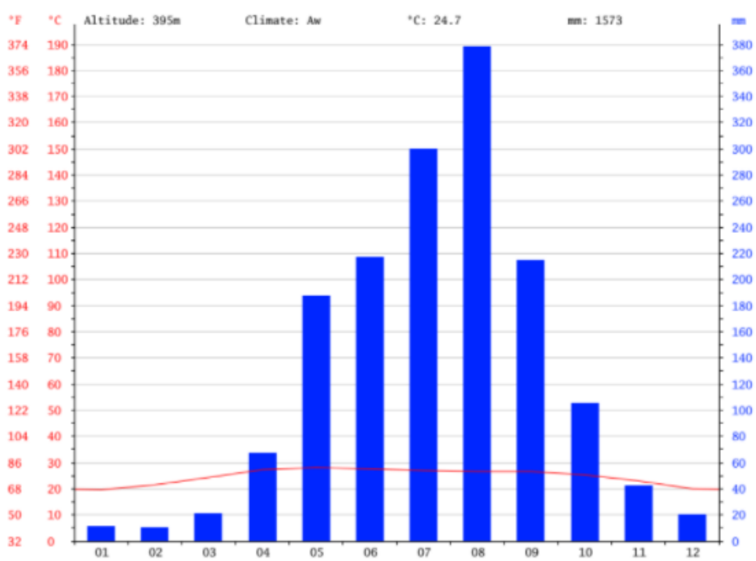


- Describe how a cave is formed.
- Using the geologic cross section below and your sedimentary rock scheme indicate with an X the layer in which a cave will develop and provide an explanation.

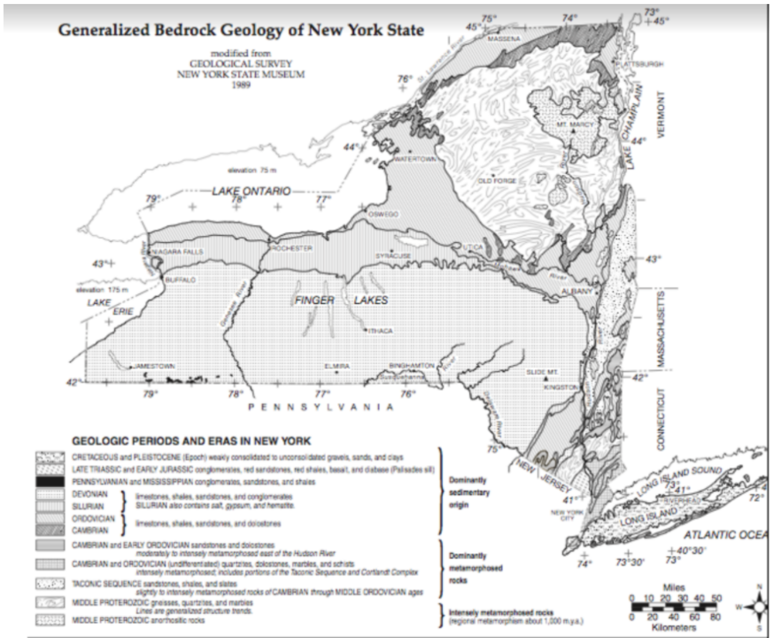


Monthly weather patterns played a role in the entrapment of the soccer team..

- Identify the data that can be used from the climograph to provide evidence of fluctuations in water levels.
- Identify what month(s) it would have been safe to travel into the cave and what month(s) to stay away from the caves?
- Explain what data you used to provide evidence of changes in cave water levels.



- Using your “Generalized Bedrock Geology of New York State” diagram in the ESRT to describe the structure and properties of the area around Old Forge, NY.
- Is it likely or unlikely that the soccer team would find themselves in a similar situation?
    - Explain your evidence that supports the claim.



- Pick a city in NY (other than Old Forge) and create a graph for their average temperature and precipitation. Go to www.weather.com to enter your city and collect your data.

Revisit the original question: Can the Thailand cave ordeal occur in New York State?
Complete the CER organizer below using evidence determined from the three previous tasks and provide reasoning statements that support your claim.

C (CLAIM) Write a statement that responds to the question.	
E (Evidence) Provide scientific data (refer to graphs) to support your claim. Free to use bullet points instead of sentences.	
R (Reasoning) Use scientific principles and knowledge about why your data supports your claim.	

Universal Supports	Targeted Supports

• Engage students in a quick lab on the different properties of water and its effect. There are a number of quick labs that can be used to demonstrate the different properties and see these properties in action. The quick lab investigations can be set up in different ways: demo, stations, or expert groups.
• Provide reading materials about the different properties of water or have them watch a short video. Here are samples:
  ○ ***Water - Liquid Awesome: Crash Course Biology***
    ■ Water - Liquid Awesome: Crash Course Biology #2
  ○ ***Water and life by Khan Academy***
    ■ Lesson summary: Water and life (article)
	• Provide word banks for anchor chart
	• Provide targeted individualized interventions
	• Small group instruction to address student misconceptions

- Provide an anchor chart that can be used for students to create a list of the different properties of water and the earth's materials and processes that are influenced by these properties. Here is an example of an anchor chart that can be used:

Properties of Water	Earth's Materials and Processes that are Influenced by these Properties

  - Provide an example and a scaffold on how to complete this anchor chart.
- Provide the format, rubrics, guidelines, exemplars, materials, and scaffold on how they should conduct their properties of water investigation

Common Misconceptions

- The atmosphere, hydrosphere, lithosphere, and biosphere do not cause changes in one another; these systems operate independently on Earth.
- Glaciers are only moving ice masses (with little to no concept of sediment transport).
- Glacial ice moves backward during glacial 'retreats.'

Source: https://teachearthscience.org/erosion.html

- Rocks do not change.
- Weathering and erosion are the same things.
- *Erosion only happens quickly.*
- *Erosion only happens after big storms.*
- *Erosion is bad.*
- *Wind and water cannot wear away the rock of a mountain.*
- *Erosion did not occur in the past.*
- *Ice can only break rock when it moves (e.g., glaciers).*

Source: California Department of Education

Culturally and Linguistically Responsive Instruction

	Guiding Questions and Connections
	- During the discussion of the different properties of water, briefly talk about the rationale of why students have to learn about the properties of water. Include how water shapes life in the discussion. The following questions can be asked: - How does water shape life and our environment? - How do you use water in your daily living? - At a personal and/or cultural level, how much do you value water? - What do you believe about how water shapes our cultural identity? Why do you believe as you do? What factors have influenced your beliefs - Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background. - Look for curriculum or activities from local, cultural, and sociopolitical organizations that can help deliver the content for this standard. - Use videos or articles that are representative of all cultural groups in your classroom. - If students are experts or interested in certain aspects of the activity or concepts being presented in the activity, assign these students to become the resource person for their area of expertise or interest. Refer students to them if they have questions about the task that relates to the resource person's expertise or interest. - If time permits and reinforcement is needed, invite guest speakers and experts from the local community or specific minorities to talk about the topic. In addition, encourage students to ask questions to the guest speaker regarding any concept that they do not understand and that needs clarification and affirmation.

Students who demonstrate understanding can:

HS-ESS2-6. **Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS2.D: Weather and Climate** • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	**Energy and Matter** • The total amount of energy and matter in closed systems is conserved.

Connections to other DCIs in this grade-band:
HS.PS1.A ; **HS.PS1.B** ; **HS.PS3.D** ; **HS.LS1.C** ; **HS.LS2.B** ; **HS.ESS3.C** ; **HS.ESS3.D**

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS3.D** ; **MS.PS4.B** ; **MS.LS2.B** ; **MS.ESS2.A** ; **MS.ESS2.B** ; **MS.ESS2.C** ; **MS.ESS3.C** ; **MS.ESS3.D**

Common Core State Standards Connections:
Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-ESS2-6)
MP.4	Model with mathematics. (HS-ESS2-6)
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-ESS2-6)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-6)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-6)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 2.6**
ESS2-6	**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.* **Description:** Mars is too cold, lacks a usable atmosphere, and the lack of a magnetic field leaves it susceptible to space weather. There is a lot of carbon dioxide located under the surface of Mars that can be used to create a greenhouse effect. Increasing the amount of CO_2 in the atmosphere could solve two of the problems above through the greenhouse effect. • YouTube video: Michio Kaku: The Cheapest Way to Terraform Mars | Big Think **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.*

The Big Thaw

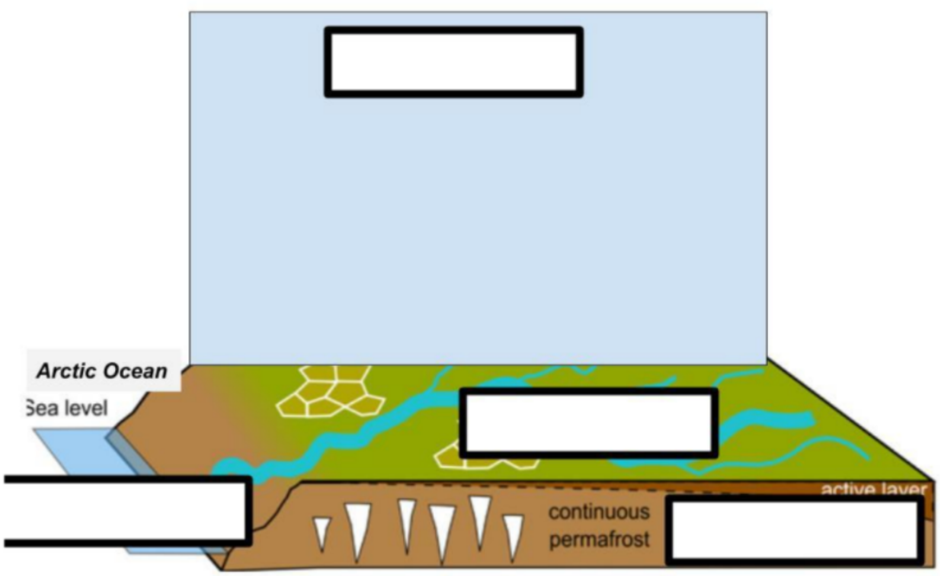
Scientists from the Lamont-Doherty Earth Observatory have been studying the melting permafrost in Alaska. The rate of melt has been dramatically increasing, and scientists are exploring the impact on local communities as well as the environment.

Permafrost is ground that remains frozen for two or more consecutive years. It is composed of rock, soil, sediments, and varying amounts of ice that bind the elements together. Some permafrost has been frozen for tens or hundreds of thousands of years, containing the remains of plants and animals that froze before they could decompose. Found under a layer of soil, permafrost can be from three feet to 4,900 feet thick.

In Noatak National Preserve, Alaska, an exceptionally warm summer in 2004 triggered this 300m long slump associated with thawing permafrost.

Thawing permafrost can damage roads as it collapses.
http://discovermagazine.com/2018/jun/something-stirs

Carbon is a fundamental part of Earth's system. How does the accelerated melting of Earth's permafrost impact this system?



To understand how melting permafrost influenced the carbon cycle in the past, the scientists examined the carbon levels in sediment that accumulated on the seafloor near the mouth of the Lena River about 11,650 years ago, when the last glacial period was ending and temperatures in the Northern Hemisphere spiked by several degrees.

Evidence from ice cores suggests that atmospheric carbon dioxide rose from about 190 parts per million to about 270 ppm during this period.

Table 1: Global Carbon Storage and Transfer:

Carbon Content	**Total amount in GIgatons of Carbon (GtC)**	
Atmosphere	720	
Geosphere	>60,000,000	
Hydrosphere	38,400	
Biosphere	2000	

Source:
The functions and sizes of the five carbon sinks on planet Earth and their relation to climate change Part I Their present sizes and locations

Time series of satellite data, like the imagery available from the Landsat satellites, allow scientists to monitor changes in forest cover. This pair of false-color images shows clear cutting and forest regrowth between 1984 and 2010 in Washington State, northeast of Mount Rainier. Dark green corresponds to mature forests, red indicates bare ground or dead plant material (freshly cut areas), and light green indicates relatively new growth.

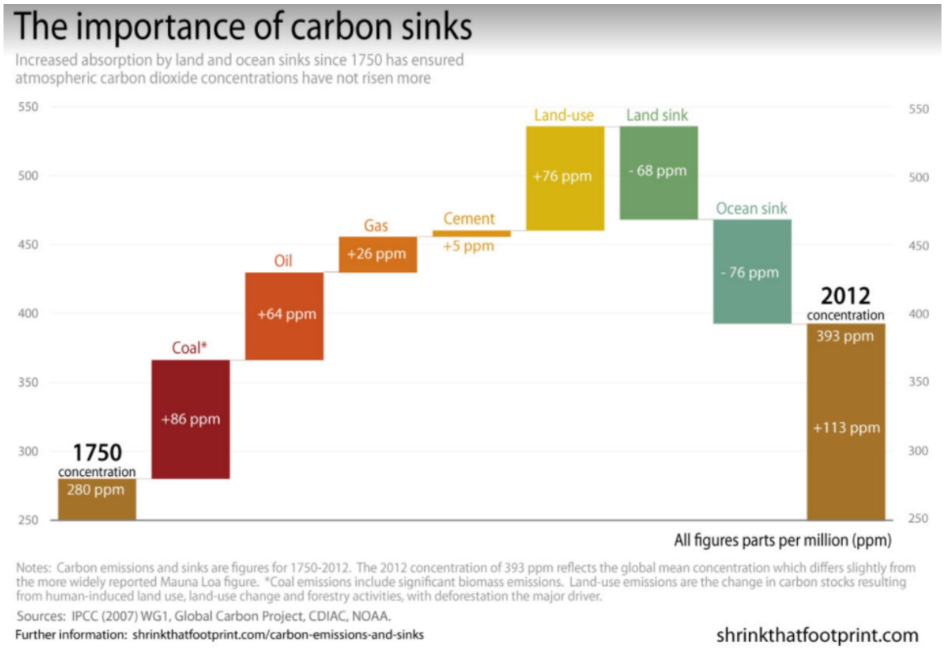
July 19, 1984

August 12, 2010

(NASA image by Robert Simmon, using Landsat data from the USGS Global Visualization Viewer.)
Source: https://earthobservatory.nasa.gov/features/CarbonCycle

1. How does this affect the carbon cycle? What stage of your carbon cycle model would be most directly affected?
    - Biogeochemical cycles
    - Photosynthesis/respiration
    - Human activity (CO_2 ⟶ atmosphere) - climate
2. Explicitly ID conservation of matter thru Carbon cycle (use last column of data table)

3. What are some limitations of your model as diagrammed? What is one feature of carbon movement in the Earth's system that you feel is limited in your model? Explain your reasoning.



[HS-ESS2-6 Assessment - The Big Thaw (NY)]

Universal Supports

- 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.

Targeted Supports

- 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

- 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.
- Have students watch a series of videos about the carbon cycle. The teacher may provide guiding questions for these videos. These can also be assigned prior to teaching the lesson unit.
- To monitor accountability, provide a note taking guide that the students will need to fill out as they watch the videos. Here is a sample of a note taking guide that can be used:

A: Key words/**Adjectives**/Main Ideas	
E: Emotion- How did this make you feel while watching? (assess beginning, middle, and end)	
I: Interesting- list 7 facts with complete sentences about what you viewed that you can share with another person.	
O: Oh WOW! What surprised you about what you saw? (2 complete sentences)	
Ummm…?!: Questions you had while watching the video. You must have 2 and use Costa's words.	

- Engage students in a brainstorming activity to identify the many substances in the Earth system and in everyday life that contain appreciable amounts of carbon.
    - A strategy called "think/pair/share" can be used to allow for interaction among students and for students to benefit from each other's thinking.

- The teacher may provide a data source for students. Our World in Data website has different recent data sets by categories.
    - Set a time frame for each group to complete their model.
    - Provide explicit directions and criteria for what the students need to show or talk about in their model

Common Misconceptions

- The atmosphere, hydrosphere, lithosphere, and biosphere do not cause changes in one another; these systems operate independently on Earth.
- Human activities cannot affect geological processes like river floods and mass wasting.
- Weather and climate are the same.
- Climate is only dictated by the location of a geographical area (latitude).
- The greenhouse effect/greenhouse gases are always bad.
- Earth is primarily warmed directly by sunlight (real-life experience, walk into the sunlight you get warm, it is difficult to disassociate sunlight from the 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).

Source: https://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html

- Carbon can be lost during transfer between sinks.
- The carbon cycle is composed of only the processes of photosynthesis and respiration.
- The only source of carbon for living things is the atmosphere.

Source: California Department of Education

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- Incorporate short breaks in between activities and have students from different cultural backgrounds share their customary ways of doing brain breaks and physical movements to relax their mind and body.
- Look for curriculum or activities from local, cultural, and sociopolitical organizations that can help deliver the content for this standard.
- Use videos or articles that are representative of all cultural groups in your classroom.
- As the students read the instructions and information from their lab activity guide or articles that they have to read, have students highlight or underline words that they do not understand and words that sparks their interest or that they are very familiar with. As you facilitate the activity, provide scaffold and explicit

	instructions to clarify vocabulary words or tasks. Have students share in class the words or statements from the reading article that sparks their interest. Affirm students statements and find means how their statements relate to others. ● If students are experts or interested in certain aspects of the activity or concepts being presented in the activity, assign these students to become the resource person for their area of expertise or interest. Refer students to them if they have questions about the task that relates to the resource person's expertise or interest. ● Invite guest speakers and experts from the local community or specific minorities to talk about the topic. In addition, encourage students to ask questions to the guest speaker regarding any concept that they do not understand and that needs clarification and affirmation. ● For activities that require the students to cross out substances and materials that do not contain a significant amount of carbon, provide students with a list of items or substances that students are familiar with and that the students can relate culturally. The teacher may also ask students to think and share other examples of materials and substances that are unique to their community. Have students talk about these materials briefly. Call other students and ask if they know about it and if there is a local counterpart for these materials. ● Be sensitive to ethnocentric views of different cultures regarding climate change. In discussing this topic, make sure to not nurture fear and intolerance so that the threats of climate change will not propagate social conflict.

Students who demonstrate understanding can:

HS-ESS2-7. **Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [*Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.*]

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
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 the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Construct an oral and written argument or counter-arguments based on data and evidence.	**ESS2.D: Weather and Climate** • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. **ESS2.E Biogeology** • The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.

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

Articulation of DCIs across grade-bands:
MS.LS2.A ; **MS.LS2.C** ; **MS.LS4.A** ; **MS.LS4.B** ; **MS.LS4.C** ; **MS.ESS1.C** ; **MS.ESS2.A** ; **MS.ESS2.C** ; **MS.ESS3.C**

Common Core State Standards Connections:
ELA/Literacy -
WHST.9-12.1 Write arguments focused on *discipline-specific content.* (HS-ESS2-7)

Grade	*NGSS Discipline*
HS	**Earth and Space Science 2.7**
ESS2-7	**Sample Phenomena**
	When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available. **How Did Plants Change Our Planet?** **Description:** From vascular to non-vascular, land plants drastically transformed our planet. Go back in time—before dinosaurs—420 million years ago to learn how they performed this feat, with evidence provided along the way. In this video, academy botanist Dr. Nathalie Nagalingum explains how, more than 400 million years ago, early plants played a notable role in adjusting Earth's physical surface as well as our planet's climate. She meets with a peer to discuss the evidence that scientists currently have to support her story. **Youtube Link:** How did plants change our planet? | California Academy of Sciences **Guiding Questions:** As you watch the video, consider the following:

- When did plants first move onto land, and how did their size and structure change over time?
- What role did early land plants play in changing our planet, both physically and chemically? *Try to list at least three examples.*
- How does carbon get "locked up" inside the living tissues of a plant? From where does that carbon originate?
- How might carbon get trapped in soil?
- Consider the time scales referenced. How long did it take plants with vascular systems to evolve? How long did it take for plants to change the climate of Earth?
- What evidence did the scientists present to support their explanation of what happened on Earth millions of years ago? *Consider one type of evidence that relates to the past, and another type of evidence that involves making observations of nature in the present day.*
- Do you find the conclusions drawn by the botanist to be compelling? Why or why not?
- What evidence was referenced, but not shown? How might you research more information to better understand those claims?

Source: [Video: How Did Plants Change Our Planet?]

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.

Figure 1 represents the amount of O2 build-up in the Earth's atmosphere. Red and green lines represent the range of the estimates while time is measured in billions of years ago (Ga).

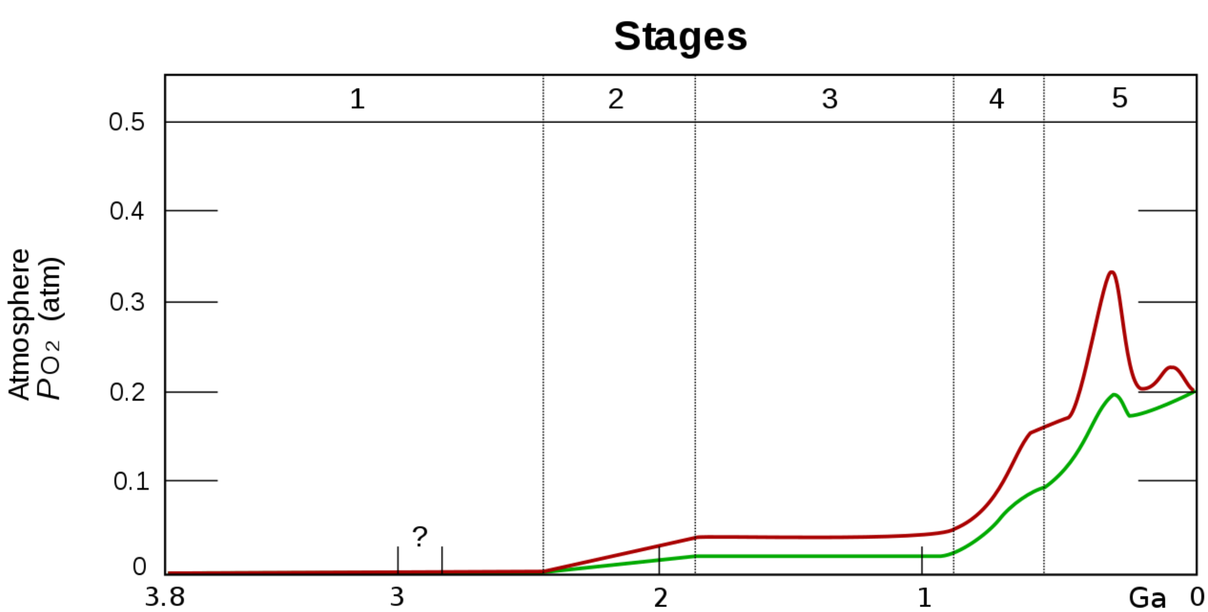
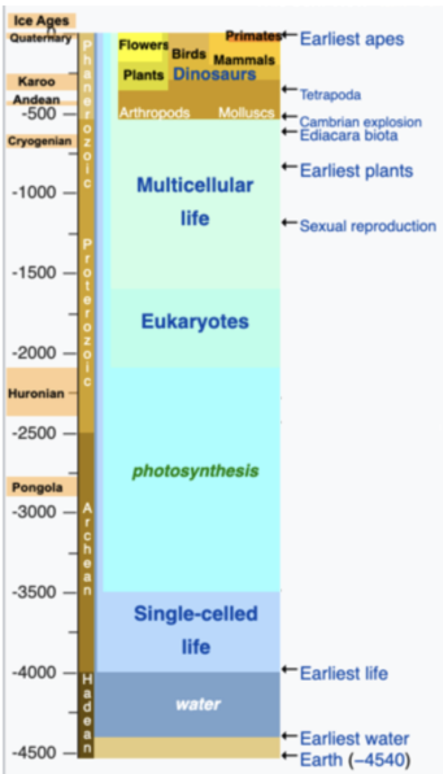


Figure 1

- What patterns do you notice over the last 3.8 billion years in Figure 1. Be sure to use data from the figure to support your answer.

Figure 2: Timeline of life on the planet.



- What events in the timeline of life coincide with changes in the levels of oxygen on the planet? You may have to refer to both figures 1 and 2 to answer this question.
- Construct an argument based on evidence for the simultaneous coevolution of Earth's systems and life on Earth.

C (CLAIM) Write a statement that responds to the question.	
E (Evidence) Provide scientific data (refer to graphs) to support your claim. Free to use bullet points instead of sentences.	
R (Reasoning) Use scientific principles and knowledge about why your data supports your claim.	

Universal Supports	Targeted Supports
• Set 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. • 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.	• Provide targeted individualized interventions • Small group instruction to address student misconceptions

- When making students organize their claim, evidence, and later on their reasoning, provide a graphic organizer that has explicit instructions.

Common Misconceptions

- The atmosphere, hydrosphere, lithosphere, and biosphere do not cause changes in one another; these systems operate independently on Earth.
- Human activities cannot affect geological processes like river floods and mass wasting.

Source: Introduction to Erosion This unit contains resources about the three agents of erosion

- The composition of the atmosphere does not change over time.
- Plants do not use oxygen.
- Organisms cannot impact the atmosphere, the oceans, or soil formation.
- Organisms do not change over time.

Source: California Department of Education

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- Incorporate short breaks in between activities and have students from different cultural backgrounds share their customary ways of doing brain breaks and physical movements to relax their mind and body.
- If available, look for curriculum or activities from local, cultural, and sociopolitical organizations that can help deliver the content for this standard.
- If students will be required to present their work/project/assignment, allow and encourage students to present in the modality of their choice and, if possible, incorporate their culture and language.
- Use videos or articles that are representative of all cultural groups in your classroom.
- If time permits and reinforcement is needed, invite guest speakers and experts from the local community or specific minorities to talk about the topic. In addition, encourage students to ask questions to the guest speaker regarding any concept that they do not understand and that needs clarification and affirmation.
- For sources of information and data that the students can use, see if there are local organizations and websites that can be provided to the students where they can get the most recent data tied to the culture and community.
- Be sensitive to ethnocentric views of different cultures regarding evolution. In discussing this topic, make sure to not nurture fear and intolerance so that the topic will not propagate social or religious conflict.

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.