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New Mexico STEM Ready! Science Standards Implementation Guide

Overview

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

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

The standards

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

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

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

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

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

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

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

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

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

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

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

Sample Phenomena

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

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

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

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

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

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

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

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

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

Classroom Assessment Items

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

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

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

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

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

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

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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 Sciences: Earth's Systems
MS-ESS2-1
MS-ESS2-2
MS-ESS2-3
MS-ESS2-4
MS-ESS2-5
MS-ESS2-6

Students who demonstrate understanding can:

MS-ESS2-1. **Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [*Assessment Boundary: Assessment does not include the identification and naming of minerals.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena.	**ESS2.A: Earth's Materials and Systems** • All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.	**Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

Connections to other DCIs in this grade band:
MS.PS1.A ; **MS.PS1.B** ; **MS.PS3.B** ; **MS.LS2.B** ; **MS.LS2.C** ; **MS.ESS1.B** ; **MS.ESS3.C**

Articulation of DCIs across grade-bands:
4.PS3.B ; **4.ESS2.A** ; **5.ESS2.A** ; **HS.PS1.B** ; **HS.PS3.B** ; **HS.LS1.C** ; **HS.LS2.B** ; **HS.ESS2.A** ; **HS.ESS2.C** ; **HS.ESS2.E**

Common Core State Standards Connections:
ELA/Literacy -
SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.*(MS-ESS2-1)*

Grade	*NGSS Discipline*
MS	**Earth 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.* Phenomena: • Minerals and rocks change throughout Earth's energy cycles. • Models of surface processes that include the Sun as a source of energy • Models of matter cycling on earth • A model or simulation that predicts the cycling of earth materials over different temporal scales • The changes in texture and composition as a rock layer is melted and then crystalizes into an igneous rock • The changes as rocks become sediment and then sedimentary rock

- Earth's hot interior provides energy to drive processes that produce metamorphic and igneous rocks.
- The changes in texture and composition of a sedimentary rock as it is deformed into a metamorphic rock

Examples include having students complete an interactive rock cycle. This can be done by providing students with different samples of rocks to identify which type they are, having them create their own diagrams highlighting the different types of rocks and where they come from, or to have them classify and group different rocks based on what they look like, where they were collected, etc. . https://ngss.nsta.org/Resource.aspx?ResourceID=751

Another way to create this phenomena is to introduce plate tectonics by examining patterns in real life that are observable and they can collect data on. Students could take an in depth look at the Mariana Trench s as well as compare how large it is to other known formations on Earth such as Mount Everest.
https://thewonderofscience.com/phenomenon/2018/6/10/the-marianas-trench-deepest-ocean

Classroom Assessment Items

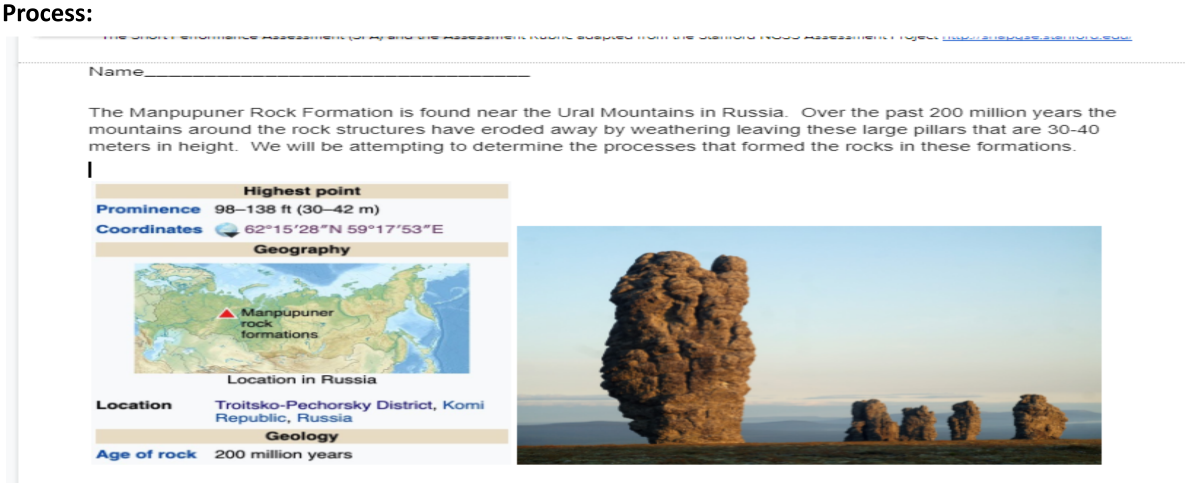
When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

Title: **Manpupuner Rock Formation**
Description: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

Link:
https://docs.google.com/document/d/1DQNd3F4j_jX12TU9pRo7_Gsaco-AEMWNTy0Yga8xkUI/template/preview

Overview: The Manpupuner Rock Formation is found near the Ural Mountains in Russia. Over the past 200 million years the mountains around the rock structures have eroded away by weathering leaving these large pillars that are 30-40 meters in height. We will be attempting to determine the processes that formed the rocks in these formations.

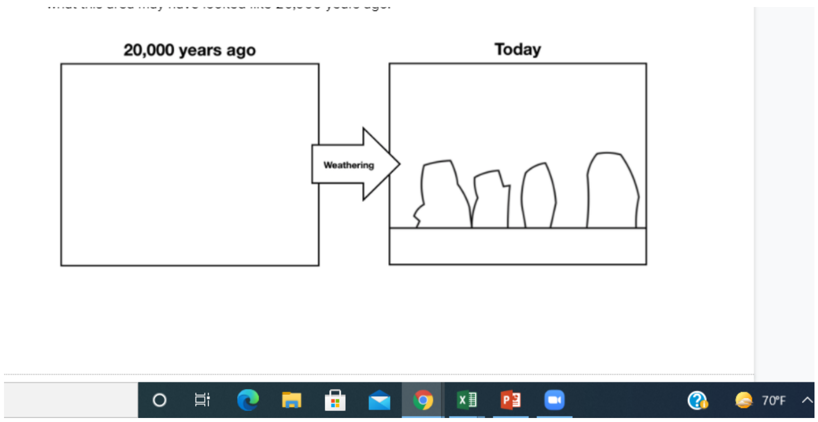
Process:


Name____

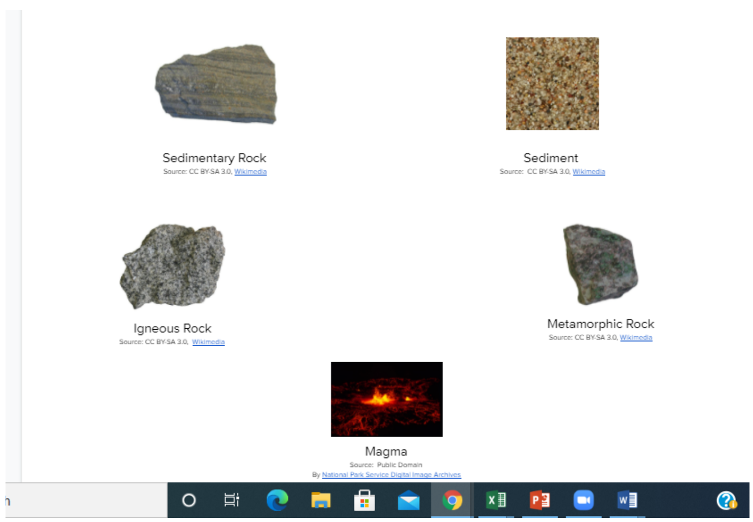
The Manpupuner Rock Formation is found near the Ural Mountains in Russia. Over the past 200 million years the mountains around the rock structures have eroded away by weathering leaving these large pillars that are 30-40 meters in height. We will be attempting to determine the processes that formed the rocks in these formations.

Highest point	
Prominence	98–138 ft (30–42 m)
Coordinates	62°15′28″N 59°17′53″E
Geography	
Location in Russia	
Location	Troitsko-Pechorsky District, Komi Republic, Russia
Geology	
Age of rock	200 million years

Watch a short video taken from the base of these rock formations. In the box below draw a model of what this area may have looked like 20,000 years ago.



Using the diagram below, draw arrows to create a model showing a possible sequence of processes forming the Manpupuner Rock Formations **starting with Magma**. Label each arrow with a number indicating the step in the process the arrow represents (i.e. 1, 2, 3, etc.). Next to the number identify the rock process that is causing the change.



Choose two of the Earth processes identified in question 2 to model in more detail. For each process mark the location, change and energy source driving the process. Then develop a model that shows this process. Your model must include **material change**, **energy flow** and **atomic arrangement**.

process. Your model must include material change, energy flow and atomic arrangement.

#	Process name	Location on Earth	Type of Change	Energy Source
		— Surface — Interior	— Chemical — Physical	— Sun — Earth's hot interior
Develop a Model				

Universal Supports

- **Layer 1:** Students will need to see models or visuals of the different Earth cycles and how they are interconnected. They also need to be provided specific examples of how energy is flowing through matter, ex, sun causing uneven heating→ wind→ weathering. Students will need to see that timescales for the rock cycle occur at different rates and how the processes are interconnected.

Targeted Supports

- **Layer 2:** Some students may need support when using and developing a model of the rock cycle. Some may also need more investigation on what qualifies as energy and what is matter. Some students may need clarification on differentiating specific processes, ex. weathering vs. erosion.

Common Misconceptions

- Students may not understand that the rock cycle is an energy driven process, and how that process is produced by the sun.
- That there is no difference between weathering and erosion.
- Matter can be created and destroyed.
- Students may have trouble understanding “New rocks” are not new matter, they are recycled.
- Minerals and rocks are the same thing.
- Rocks do not change.
- Rocks were formed where they are found.
- Wind and water cannot wear away rock.
- All processes in the rock cycle occur at the same rate and/or quickly or slowly.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

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The teacher could use these questions in science classroom discussions to bring out student’s thoughts, ideas and cultures:

	Validate-Ask the students what knowledge and experiences have you had that might help us as a class explain what's happening with the cycling of matter and how energy flows through these cycles? Ex. The teacher can ask: What transformation or cycling of matter have you observed? What matter have you cycled today and what energy has flowed through? **Affirm-**Ask the students what questions do we need to answer to test your ideas about what's happening with matter on Earth and energy transfer? Ex. Students can express their views on decomposition and how matter is reused. **Build & Bridge**-Why does this phenomenon matter to you, to your community or others, and to scientists? Ex. Students can discuss the finite nature of these materials and how they are being used today.

Students who demonstrate understanding can:

MS-ESS2-2. **Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.	**ESS2.A: Earth's Materials and Systems** • The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. **ESS2.C: The Roles of Water in Earth's Surface Processes** • Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.	**Scale Proportion and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Connections to other DCIs in this grade band:
MS.PS1.B ; **MS.LS2.B**

Articulation of DCIs across grade-bands:
4.ESS1.C ; **4.ESS2.A** ; **4.ESS2.E** ; **5.ESS2.A** ; **HS.PS3.D** ; **HS.LS2.B** ; **HS.ESS1.C** ; **HS.ESS2.A** ; **HS.ESS2.B** ; **HS.ESS2.C** ; **HS.ESS2.D** ; **HS.ESS2.E** ; **HS.ESS3.D**

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. (MS-ESS2-2)
WHST.6-8.2	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-ESS2-2)
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. *(MS-ESS2-2)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (MS-ESS2-2)
6.EE.B.6	Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. *(MS-ESS2-2)*
7.EE.B.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-ESS2-2)*

Grade	*NGSS Discipline*
MS	**Earth 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.* Suggested phenomena for this standard need to be observable, interesting, complex and relatable to the student. The phenomena can be physical, graphical or conceptual. Phenomena: ● Earth's processes influence the Earth's surface in large and small scales over time. ● The shape/surface of the Grand Canyon has changed over time ● Data or observations from an investigation of a geological process (e.g., soil erosion)

- Examples of potential phenomena for items that focus on comparing duration and scale of examples of a geological process (e.g., erosion by landslide or soil creep, different types of volcanic eruptions , movement along faults under different conditions)
- Before and after images of a surface feature after a sudden geological event (e.g., a landslide)
- A series of images of a change over time of surface features as a result of erosion and deposition (e.g., delta formation/degradation)
- A model of a surface feature formed by plate tectonics (e.g., a mountain range)
- Examples of potential phenomena for items that focus on recognizing that present-day geological processes operated in the past

A way to create a phenomena for how geoscience processes can change the landscape of Earth over time is to look at the Grand Canyon and examine how it has changed to become what it is today.
https://thewonderofscience.com/phenomenon/2018/5/13/how-was-the-grand-canyon-formed

Students could also take an in depth look at the Mariana Trench as an introduction to plate tectonics and discover how they have changed Earth's surface over time and make theories about how they will shape the Earth in the future.
https://thewonderofscience.com/phenomenon/2018/6/10/the-marianas-trench-deepest-ocean

Another phenomenon to demonstrate this standard would be for student to relate how volcanoes and earthquakes are related to plate boundaries using models, maps and real life data.
https://ngss.nsta.org/Resource.aspx?ResourceID=831

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.

Title: The Mysterious Chocolate Hills

Description: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales

Link:
https://docs.google.com/document/d/1UpGMzPO2W7iurx5F4kPS9LQGFnFca2QxmsQG7k2aBYo/template/preview

Overview: Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.

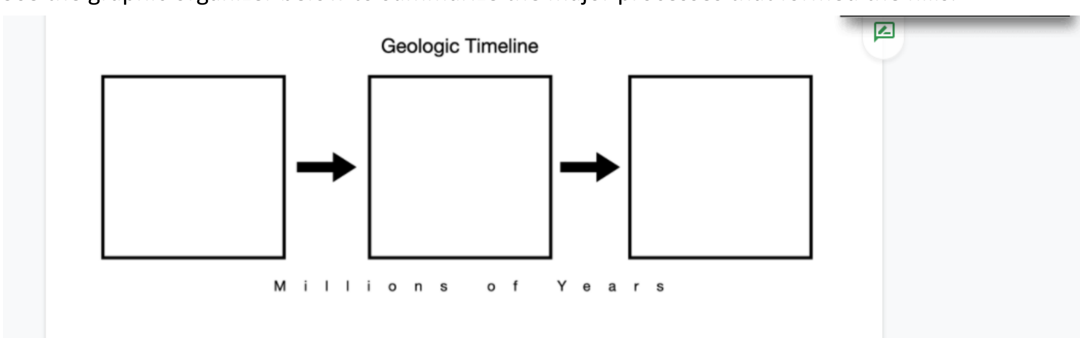
Process: The Chocolate Hills are a mysterious geological formation in the Bohol Province of the Philippines. Over 1700 hills are spread over 20 square miles. The hills are covered with grass that turns brown during the dry season.

This gives the hills their characteristic color. Several local legends explain how the hills may have formed; including a story of two giants who fought for days throwing rocks at each other. (image)

Watch the National Geographic Video featured to the left. The video summarizes the origin of the hills in the following way:

"the Chocolate Hills, formed naturally, over millions of years. The land's limestone base formed from skeletons of sea life. Geologic processes lifted the rock, and water slowly eroded it. Similar processes carve limestone around the world, but the Chocolate Hills' combination of shape and uniformity makes them unique."

1. Use the graphic organizer below to summarize the major processes that formed the hills.



Scientists* have investigated the consistent shape of the hills. Carefully look through some of their photographic and geologic evidence on the next couple pages. You will be using this evidence to construct an explanation of how geoscience processes have shaped the Chocolate Hills at varying time and spatial scales.

Fig. 8: The extent of "Chocolate Hills" (section of Batuan) (Photo: J.N. Salomon).

Fig. 15: Erosion at one of "Chocolate Hills" and loss of soil (Photo: J.N. Salomon).

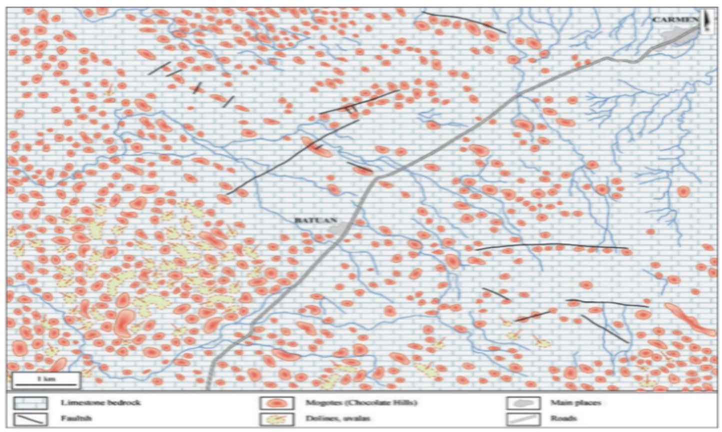


Fig. 10: The "Chocolate Hills" of the Batuan section.

Fig. 7: A breakdown from a mogote clearly showing the coral origin of the limestone (branch section of Acropora) (Photo: J.N. Salomon).

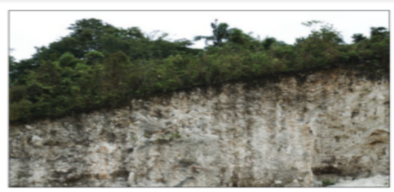
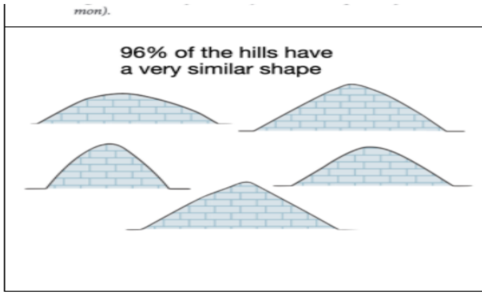
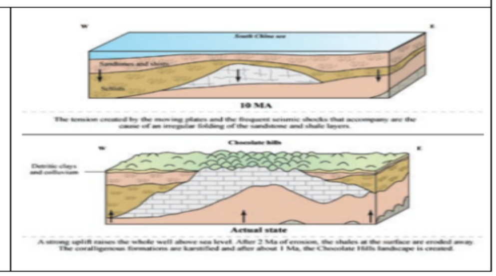


Fig. 12: Cross-section of a "Chocolate Hill" (under rich vegetation the soil is rather thin, alteration is powerful: > 20 m) (Photo: J.N. Salomon).

Figs. 16 & 17: Professional hydraulic development of traditional rice-fields by karst water (Sierra Bullones section) (Photo: J.N. Salomon).

mon).





*Salomon JN. A Mysterious Karst: the "Chocolate Hills" of Bohol (Philippines). AC [Internet]. 2011Dec.28 [cited 2020Dec.4];40(3). Available from: https://ojs.zrc-sazu.si/carsologica/article/view/3

.

2. Construct an explanation that uses evidence to answer the following question:

How have geoscience processes shaped the Chocolate Hills at varying time and spatial scales?

Claim	
The geoscience processes of ____ have shaped the Chocolate Hills at varying time and spatial **scales**.	
Evidence	
Use qualitative evidence from the photographs and figures on the preceding two pages to support your claim.	
Reasoning	
Use reasoning to connect the appropriate evidence to the claim	

Universal Supports	Targeted Supports

• **Layer 1:** Students will need visuals or models of how plate tectonics can and have shaped the landscape of Earth including different tectonic types and which land features they tend to form, ex, convergent boundaries can form mountains. Students will need to have timelapses shown of different areas to prove the changes, ex, timelapse of the continents. students will need to see examples of how land structures differ depending on where they are and what affected them. ex. Why certain parts of the US have mountains while other places have plains.	• **Layer 2:** Some students may need further support modeling processes and scale proportions with the Earth's continents. Some may also need help on differentiating between land structures and the ocean floor. Some students will need to see direct evidence of how land and sea structure will continue to change as the Earth ages.

Common Misconceptions

- Students may not understand that all things on Earth all have time scales, they are not always the same
- All places around the US and the globe have the same surface and land structures
- All changes occur around the same timeline and ar not dependent on certain events
- The ocean floor is ALWAYS the same.
- Rock layers are deposited or formed at the same rate.
- Rock layers erode at the same rate.
- Mountains are permanent structures, unchanged over long periods of time.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

.
The teacher could use these questions in science classroom discussions to bring out student's thoughts, ideas and cultures:

Validate-Ask the students what knowledge and experiences have you had that might help us as a class explain what's happening with changes in the Earth's surface?
Ex. The teacher can ask the students what they think about what caused the aspects of the Earth's surface and if they have changed through time. Students can express their beliefs or opinions on how different land features came about.

Affirm-Ask the class what questions do we need to answer to test your ideas about how the Earth's surface (ocean and land) have changed?
Ex. Students have the opportunity to investigate their own beliefs and compare them to known geoscience processes.

Build & Bridge-Why does this phenomenon matter to you, to your community or others, and to scientists?
Ex. The teacher can ask students what land or ocean formations impact or influence your daily life, ie. Albuquerque Box Effect that helps hot air balloons fly, mountains are East in Albuquerque.

Students who demonstrate understanding can:

MS-ESS2-3. **Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [*Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to provide evidence for phenomena. - ***Connections to Nature of Science*** **Scientific Knowledge is Open to Revision in Light of New Evidence** • Science findings are frequently revised and/or reinterpreted based on new evidence.	**ESS1.C: The History of Planet Earth** • Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. *(HS.ESS1.C GBE),(secondary)* **ESS2.B: Plate Tectonics and Large-Scale System Interactions** • Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.	**Patterns** • Patterns in rates of change and other numerical relationships can provide information about natural systems.

Connections to other DCIs in this grade band:
MS.LS4.B

Articulation of DCIs across grade-bands:
3.LS4.A ; **3.ESS3.B** ; **4.ESS1.C** ; **4.ESS2.B** ; **4.ESS3.B** ; **HS.LS4.A** ; **HS.LS4.C** ; **HS.ESS1.C** ; **HS.ESS2.A** ; **HS.ESS2.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. *(MS-ESS2-3)*

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ESS2-3)

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ESS2-3)

Mathematics -

MP.2 Reason abstractly and quantitatively. (MS-ESS2-3)

6.EE.B.6 Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. *(MS-ESS2-3)*

7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-ESS2-3)*

Grade	NGSS Discipline
MS	**Earth 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.* Phenomena: ● Past plate tectonic movement has produced fossils, rocks, continental shapes and seafloor spreading. ● Maps or tables of the locations of similar fossils or rocks on different continents ● Maps showing the coastline and outlines of the continental shelves ● Maps showing the locations of mid-ocean ridges and trenches and ages of the seafloor ● Diagrams and tables with the ages of the seafloor and distances from a mid-ocean ridge

- Examples of potential phenomena for items that focus on comparing the ages of rocks from the seafloor crust and from continental crust
- Examples of potential phenomena for items that focus on evidence of possible ancient plate tectonic boundaries (e.g., within the Appalachian Mountains) on continents
- Examples of potential phenomena for items that focus on the evidence for the beginnings of plate tectonics early in Earth's history

To create a phenomena that provides evidence of past plate motions by looking at the distribution of fossils and rocks, students can reconstruct a position of large islands and continents as they appeared 220 million years ago as a review of plate tectonics. They could then further their knowledge by looking at where similar rocks and fossils have been found from different continents and compared to the supercontinent Pangea to provide evidence for past plate movement.
https://ngss.nsta.org/Resource.aspx?ResourceID=499
https://ngss.nsta.org/Resource.aspx?ResourceID=140

Students could also look at the deep sea drilling project to look for evidence of seafloor spreading in the mid Atlantic ridge.
https://ngss.nsta.org/Resource.aspx?ResourceID=753

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.

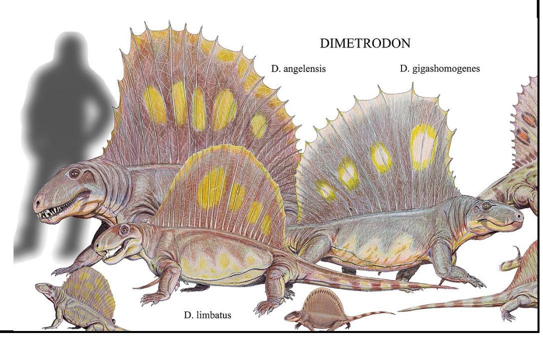
Title: Putting Together a Permian Puzzle

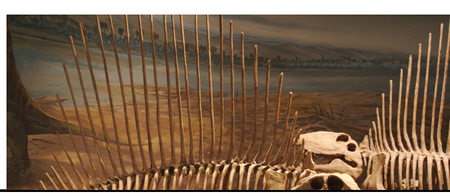
Description: Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

Link:
https://docs.google.com/document/d/1W9Jd7v-R3BeKZperW0B6dOdAyYk8FUD6vl-srlWlhE0/template/preview

Overview: Analyze and interpret data to provide evidence for phenomena.

Process: Putting Together a Permian Puzzle
The Permian Period spans 47 million years and started nearly 300 million years ago. The Permian saw the evolution of a diverse group of tetrapods (four-legged animals) like the Dimetrodons featured to the right. Scientists have gathered fossils around the world to better understand organisms that lived during this time.





Not only were the organisms on the planet different from today but the continents themselves were in different locations. You will be using the location and time period of various Permian fossils to reconstruct the arrangement of plates during this time.

1. Look at each figure on the next two pages and use them to complete the questions on the table below.

Figures	What patterns do you see? Be sure to use data from the figure to support your answer
Figure 1: Dimetrodon Fossil Locations	
Figure 2: Mesosaurus Fossil Locations	
Figure 3: Glossopteris Fossil Locations	
Figure 4: Titanophoneus Fossil Locations	

Figure 1: Dimetrodon Fossil Locations

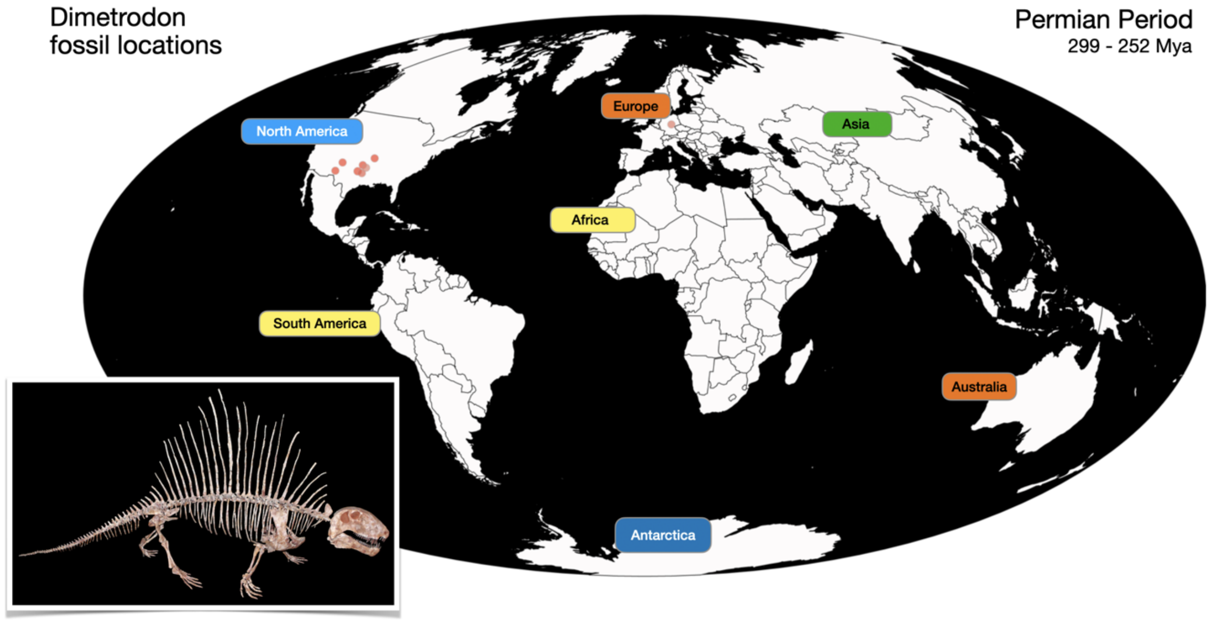


Figure 2: Mesosaurus Fossil Locations

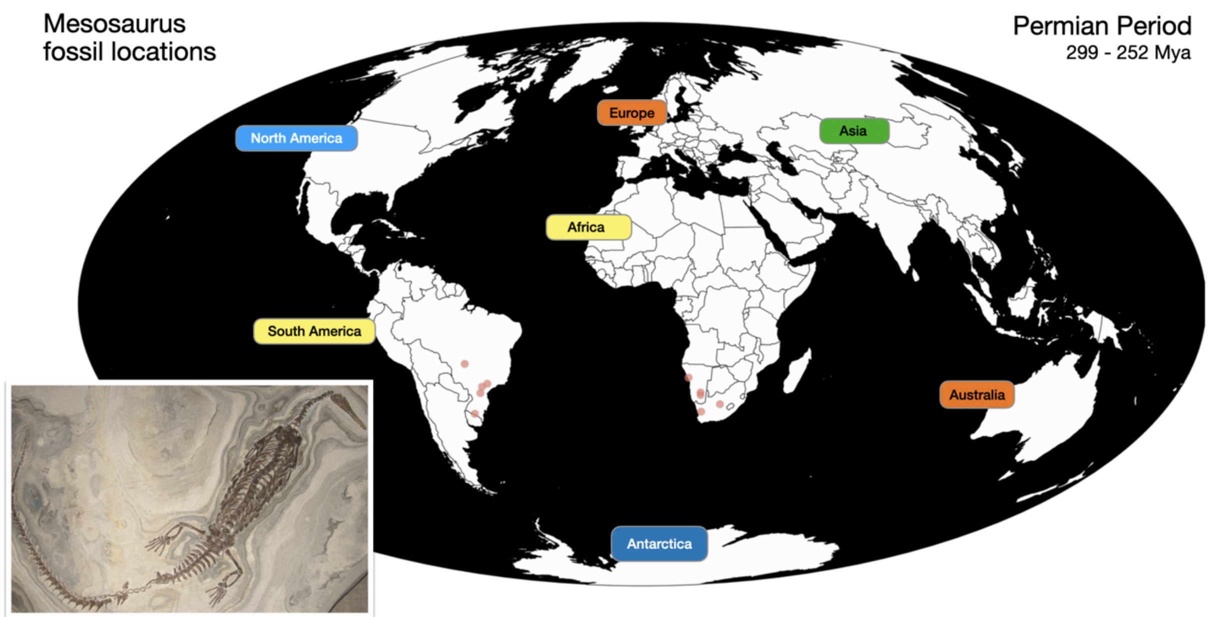


Figure 3: Glossopteris Fossil Locations

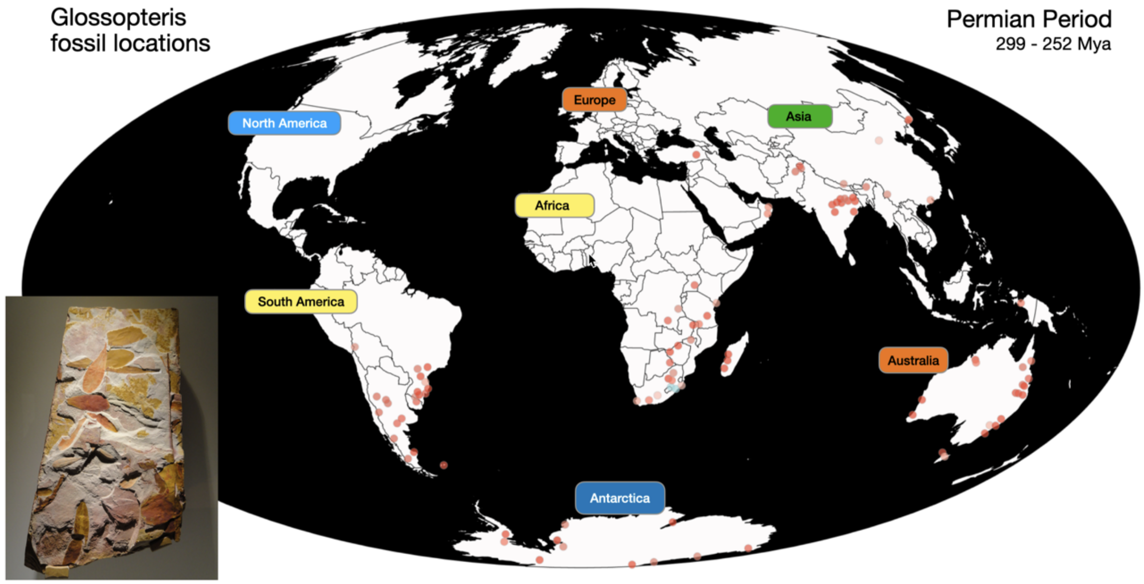
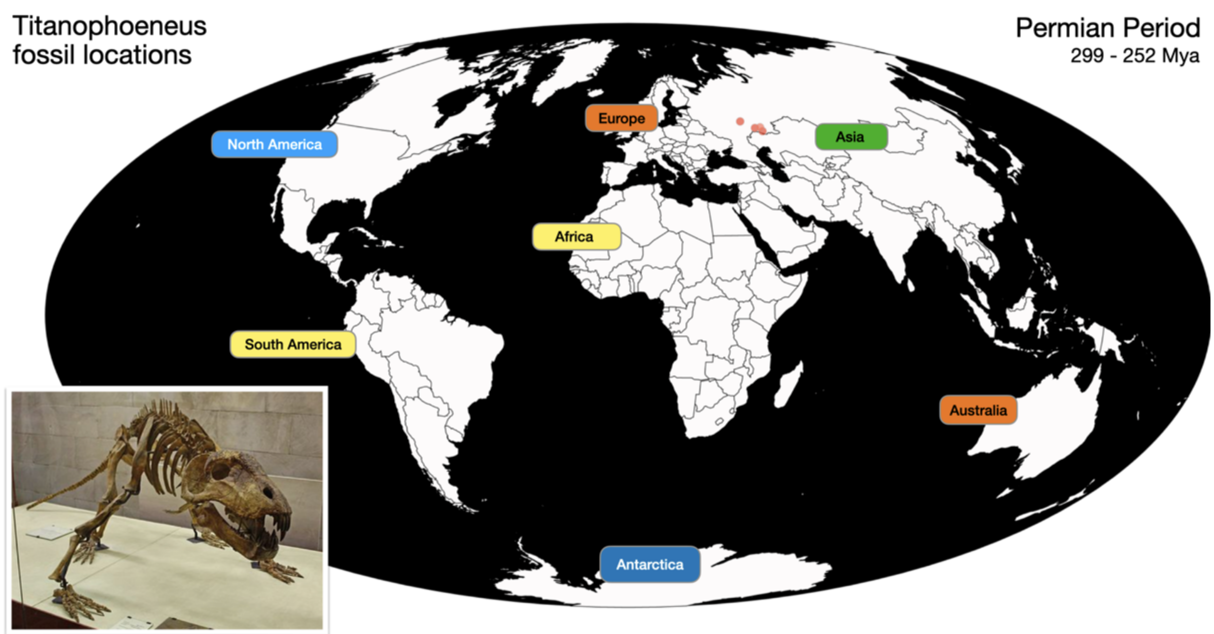


Figure 4: Titanophoneus Fossil Locations



Use the patterns of fossils to answer the following questions.

1. How were the continents arranged during the Permian Period?

Claim
Use the Google Drawing to rearrange the Permian Period Puzzle. 

Evidence	
Use qualitative evidence from the photographs and figures on the preceding two pages to support your claim.	

Reasoning	
Use reasoning to connect the appropriate evidence to the claim	

1. What additional fossil locations would help you create a more accurate puzzle? Why?

Universal Supports	Targeted Supports
• **Layer 1:** Students will need to be provided with visual evidence of plate motion, ex. similar fossils in very different areas. Students will need to see a visual model of how the continents and land masses have changed over time, ex. Pangea to modern day. Students will need to see a model of how plate tectonics has influenced the shifting of continents over time.	• **Layer 2:** Some students may need help in analyzing specific data that is related to the evidence of how continents and land features are constantly changing to show how the Earth is continually changing.

Common Misconceptions

- Land masses are stagnant.
- Students may think that fossils are specific to geologic areas.
- Students may think that continents could fit perfectly together again like a puzzle.
- Students may think that fault lines are not active, on land or in sea.
- Students may think that the Earth is done changing.
- Only continents move.
- The edges of continents are plate boundaries.
- The seafloor is all the same age.
- Earth is not a dynamic system

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

The teacher could use these questions in science classroom discussions to bring out the student's thoughts, ideas and cultures:.

Validate-Ask the students what knowledge and experiences have you had that might help us as a class explain how the continents have been shaped from plate movement?
Ex. Students can express how they think the Earth used to look? What do students know about plates (plate tectonics)?

Affirm-Ask the students what questions do we need to answer to test your ideas about the evidence provided of plate motion?
Ex. Building on prior knowledge, students will be asked to compare their ideas to the scientific concepts of geographical positions of similar fossils, the shapes of the continents, and seafloor structures.

Build & Bridge-Ask the students why does this phenomenon matter to you, to your community or others, and to scientists?
Ex. Students can be asked to predict how these processes affect their future and the future of humanity?

Students who demonstrate understanding can:

MS-ESS2-4. **Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.** [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [*Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to describe unobservable mechanisms.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. • Global movements of water and its changes in form are propelled by sunlight and gravity.	**Energy and Matter** • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

Connections to other DCIs in this grade band:
MS.PS1.A ; **MS.PS2.B** ; **MS.PS3.A** ; **MS.PS3.D**

Articulation of DCIs across grade-bands:
3.PS2.A ; **4.PS3.B** ; **5.PS2.B** ; **5.ESS2.C** ; **HS.PS2.B** ; **HS.PS3.B** ; **HS.PS3.D** ; **HS.PS4.B** ; **HS.ESS2.A** ; **HS.ESS2.C** ; **HS.ESS2.D**

Common Core State Standards Connections: N/A

Grade	*NGSS Discipline*
MS	**Earth 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.* Phenomena: • Earth's water system is caused by the energy from the sun and the force of gravity. Look at activities below for ideas on how to demonstrate this. • The movement of water from the atmosphere to plants and from plants to the atmosphere • The movement of water over landmasses • Energy transfers to and from the environment during phase changes such as evaporation and condensation. • The roles of solar energy and gravity on the movement of water, leading to cloud formation, precipitation, and other weather processes • The relationship between energy in the atmosphere and oceans and the volume of glacial ice on Earth's surface • The movement of water through aquifersA phenomenon that focuses on weather and climate that reflects how Earth's water system is by energy from the sun and gravity would be to have students build a theoretical mountain to help increase rainfall and explore how that would benefit NM. https://thewonderofscience.com/phenomenon/2018/6/10/uae-building-a-mountain-to-increase-rainfall

Students could also take a look at a water molecule more in depth by becoming one theoretically and traveling through the water system allowing them to see in depth how the water cycle works and flows throughout Earth's system.

https://ngss.nsta.org/Resource.aspx?ResourceID=738

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.

Title: Modeling the Hydrologic Cycle
Description: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
Link:
https://docs.google.com/document/d/1nYc2aFSQOtuKqD82XAYsnzdZVMGJkXCrps5-PSiKK6U/template/preview

Overview:
Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
Global movements of water and its changes in form are propelled by sunlight and gravity

Process:

Background:

Scientists build physical models to better understand natural phenomena. You will be observing and modeling matter and energy changes in this physical model and then applying it to similar processes in the Earth's hydrologic cycle.

Physical Model:

A physical model was created to investigate the unobservable mechanisms driving the hydrologic cycle. The sealed jar, shown to the right, initially contained colored water, ice cubes, a rock and air. It was placed outside on a sunny winter day. A time-lapse video was recorded for one hour.

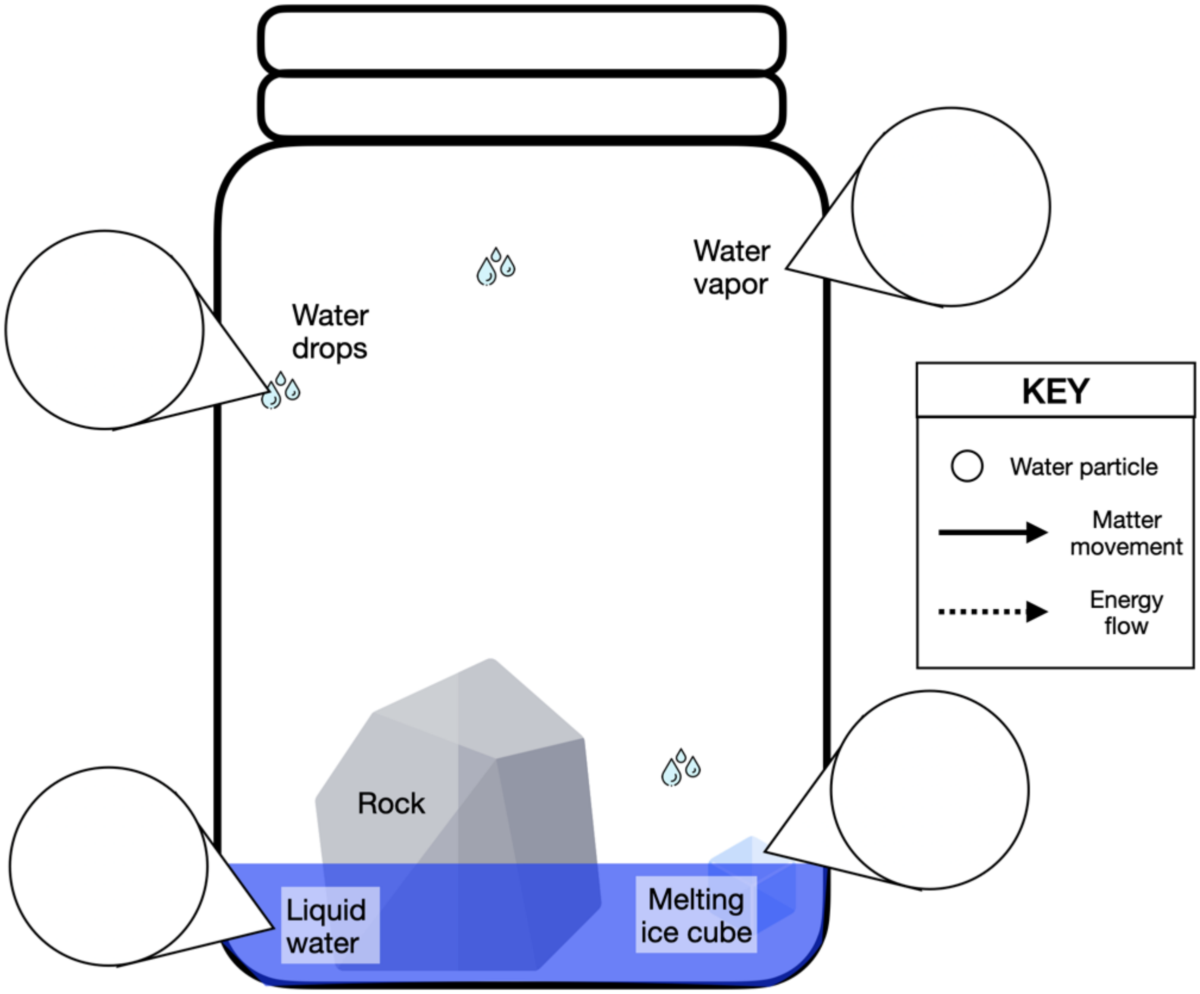
0 minutes 30 minutes 60 minutes

1. Use the following graphic organizer to answer the following questions.

What physical changes do you observe in the model over time?
How is the transfer of energy driving this change?

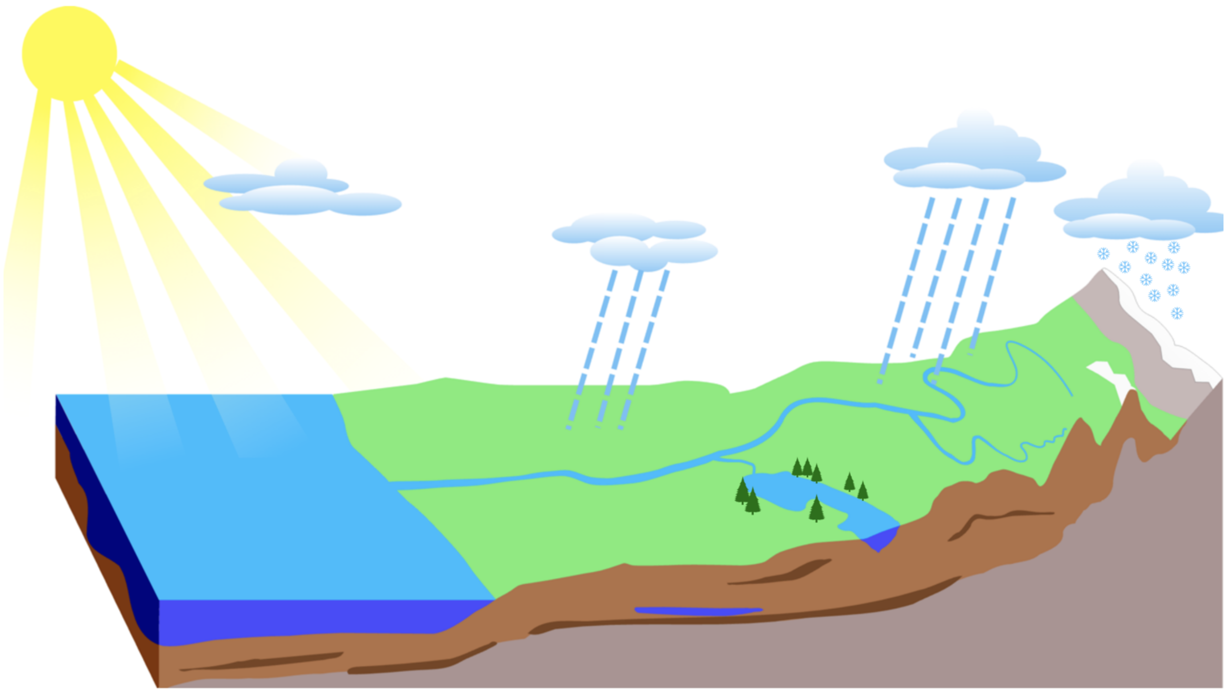
Modeling:

2. Use the template below to model matter and energy flow in the physical model. Your model should include the following.
    a. Particle model of liquid water, water drops, water vapor and solid water
    b. Cycling of matter in the system
    c. Identify two periods of time when the transfer of energy drives the motion of matter.



Hydrologic Modeling:

3. Annotate the diagram below using arrows and zoom in bubbles to identify the following processes. **condensation, crystallization, downhill flow, evaporation, precipitation, transpiration.**



4. Describe how the energy from the sun and the force of gravity interact during each of the processes labeled in your hydrologic model. Note: If there is no relevant interaction leave the square blank.

Process	Energy from the Sun Added or Removed	The Force of Gravity
condensation		
crystallization		
downhill flow		
evaporation		
precipitation		
transpiration		

Universal Supports	Targeted Supports
• **Layer 1:** Students will need to see visuals and models in different modalities (videos, skits, demonstrations, readings, graphics) of how the cycle works. Students will need to understand how the Sun and gravity drive this process, ex. investigating the water in a closed jar with ice that is allowed to heat up demonstrating matter and energy changes. Students will need explicit examples of gravity's effects on the water cycle.	• **Layer 2:** Some students may need further investigations on modeling how the matter, water, is only changing forms not being created or destroyed and that energy is driving the process. Some students will need more in depth examination on the differences of the complex topics such as transpiration and groundwater and how they are connected but not the same.

Common Misconceptions

- Do not understand that the Sun provides most of the energy in our system.
- Think of the water cycle as linear
- Don't understand more complex topics of transpiration, groundwater, etc.
- Takes an input of energy for water to change state.
- Students often cannot see gravity as a contributing factor.
- Living things are not part of the water cycle.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

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Validate-Ask the students what knowledge and experiences have you had that might help us as a class explain what's happening with water on Earth?
Ex. Students can generate a list of ways water moves and changes on Earth. What are students' beliefs and perceptions of water?

Affirm-Ask the student what questions do we need to answer to test your ideas about what's happening with the Water cycle?
Ex. What actually drives this process and compares to student's prior ideas?

Build & Bridge-Ask the students why does this phenomenon matter to you, to your community or others, and to scientists?
Ex. Why is water important? Why do we need freshwater? What role does water play in your life?

Students who demonstrate understanding can:

MS-ESS2-5. **Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

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 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions. • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. **ESS2.D: Weather and Climate** • Because these patterns are so complex, weather can only be predicted probabilistically.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Connections to other DCIs in this grade band:
MS.PS1.A ; ***MS.PS2.A*** ; ***MS.PS3.A*** ; ***MS.PS3.B***

Articulation of DCIs across grade-bands:
3.ESS2.D ; ***5.ESS2.A*** ; ***HS.ESS2.C*** ; ***HS.ESS2.D***

Common Core State Standards Connections:
ELA/Literacy -

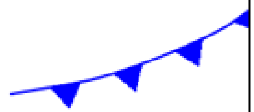
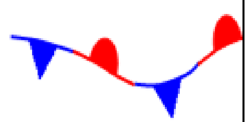
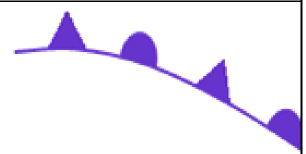
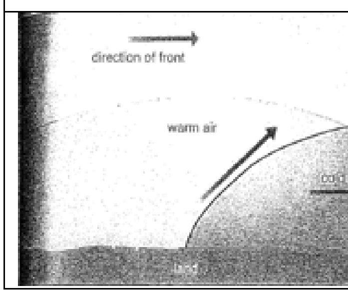
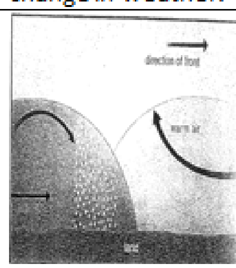
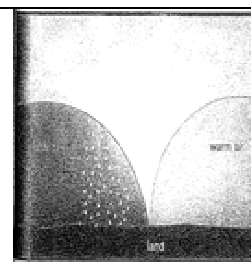
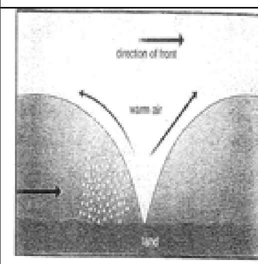
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-ESS2-5)
RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ESS2-5)
WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. *(MS-ESS2-5)*

Mathematics -

MP.2 Reason abstractly and quantitatively. (MS-ESS2-5)
6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-ESS2-5)

Grade	*NGSS Discipline*
MS	**[Earth 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.* 1. Phenomenon: Hot and Cold air/water masses react in characteristic ways where they meet. a. Split Tank: In a split tank, pour one side with warm water colored red and the other side with cold water colored blue. Measure and record the temperature of each water sample. Remove the divider in the spit tank and observe how the warm and cold water move and interact. Make sure to remind students that water and air behave in similar ways so they make connections to the atmosphere. Students should record their observations. (video of phenomenon- https://www.youtube.com/watch?v=jch-sxx71ko)

b. Have students analyze the following diagram to learn about the complex interactions of air masses. Have students return to the picture of their observations from the split tank phenomenon and mark the types of fronts that they observed.

Warm Front	Cold Front	Stationary Front	Occluded Front
			
Occurs when slower-moving warm air is instead replaced with cooler air. When it is replaced with cool air, the warm air will still take over in the end. It gets warmer and more humid after.	Occurs when fast moving cold air comes in and meets the warm retreating air. After the front moves through, temperatures and humidity decrease.	Happens when air masses are not moving. With this there is a boundary between cold masses and warm.	When a warm front is taken over by a cold front. The warm is over the cool air masses.
This produces light, moderate rain.	Rain normally comes with this. Violent weather may also occur because the change in weather.	It could be warm or cool with long periods of rain.	Periods of Rain
			

2. Mountain ranges influence weather patterns
3. Formation and movement of major weather events

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.

1. In small groups, have students draw a model of what they just observed in the split tank. What caused the water to move this way? Share out the observations as a whole. This same model should be revisited after discussing the diagram about fronts and adding labels for what type of fronts are observed in the split tank model.
   SEP- Developing and Using Models
   CCC- Cause and Effect

2. Weather Watch

Summary

Students follow weather forecasts to gauge their accuracy and produce a weather report for the class. They develop skills of observation, recording and reporting.

Introduction/Motivation

Everybody loves the occasional "snow day." But, can you trust the local weather service to deliver a nice blizzard on cue? Even though weather reporters would like to take credit for good weather and avoid blame for the not-so-good, all they can really do is try to report the weather as accurately as possible. Fortunately, they have advanced technology working for them, such as **Doppler radar, satellite imagery** and weather **forecasting** software programs.

With the advent of satellite imaging, Doppler radar and sophisticated weather modeling software, weather forecasting is becoming increasingly accurate. Jokes about the unpredictable nature of weather are still common — "If you don't like the weather around here, wait five minutes!" — but the local meteorologist is not quite as likely to take the blame. If it rains on your parade or picnic, that's probably because you didn't watch the latest **weathercast**.

In this activity, you are going to take a closer look at how the weather report is delivered in your area. You will keep a record to see how **accurate** the weather report is. At the same time, you will observe how the report is presented so you can produce a weather show for your class. In the process, you will become better acquainted with weather terminology and learn how the latest weather forecasting technology works.

Procedure

Background

During this activity, students gauge the accuracy of local weather reports for themselves, and at the same time observe the local weather presenter. The goal is to present their own weather report for the class. In the process, students become more familiar with weather terminology (see the Word Origins & Metaphors: Take Their Word for It! literacy activity), learn about how weather forecasting technology works, and develop presentation skills.

If possible, videotape one or more evening weathercasts (4-6PM) and view in class, discussing how the weather is presented. Help the students identify the segments of the broadcast, noting the use of maps and symbols (see Figure 1). Discuss the meaning of weather symbols and basic terminology used by the meteorologist. Critique the style of presentation. The objective is to prepare the students to produce their own weathercast.

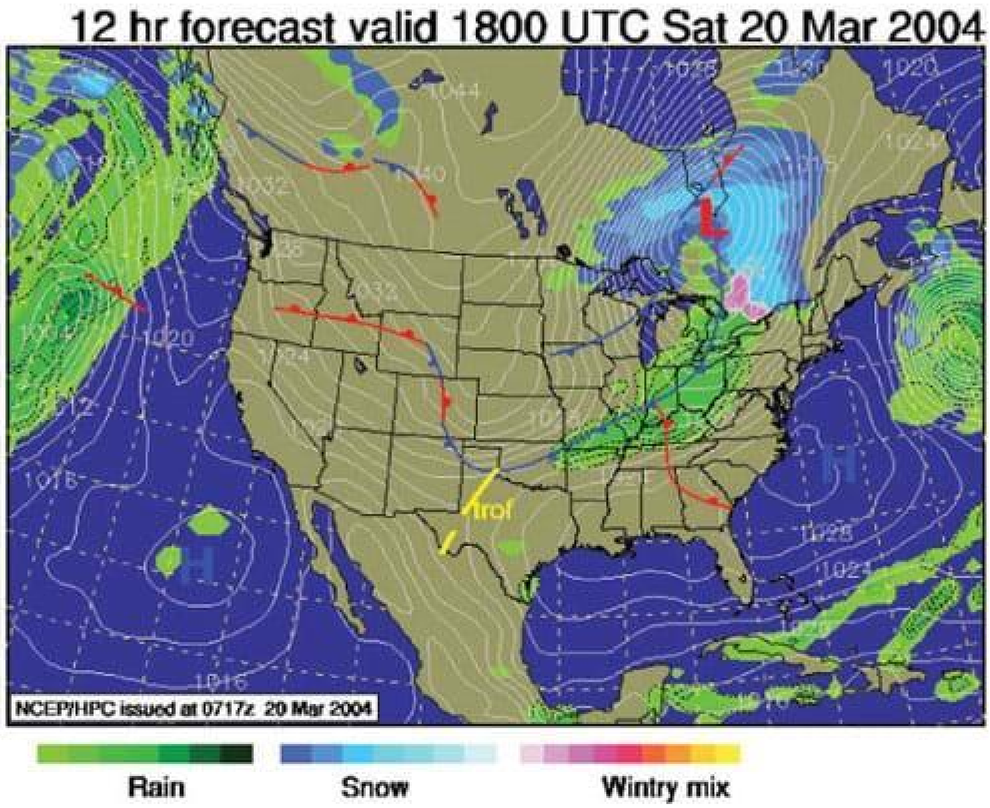


Figure 1. A 12-hour weather forecast map, created by University Corporation for Atmospheric Research (UCAR). See http://www.ucar.edu/ucar/weather-map.html for today's map.

Consider taking the students on a field trip to a local television station to see for themselves how a weather report is produced, and meet local weather personalities they have seen on TV.

Observing

Background research: Watch the evening weather report (4-6PM time slot) on your favorite local news channel for one week. Using the Weather Watcher Worksheet, record the forecast for the following day, noting the basic weather forecast description: High and low temperatures, sunny/cloudy, rainy/snowy/windy, chance for precipitation, etc. At the same time, take some notes about the presentation itself. Observe the weather reporter's presentation style. Notice how s/he uses maps and explains weather phenomena for the viewer. Learn the tricks of the trade! The following day, observe the weather and record the actual weather conditions. Was the forecast **accurate**?

Weather Watcher Worksheet

Date	Weather Conditions		Temperatures Daytime High & Overnight Low		% Chance of Precipitation	Notes on Weather Presentation
	Forecast	Actual	Forecast	Actual		
			/	/		
			/	/		
			/	/		
			/	/		
			/	/		
			/	/		
			/	/		

What was the source of your daily weather forecast? ______________________________

How accurate was each day's weather forecast?

Air Pollution: Lesson 5, How Predictable! Activity — Weather Watcher Worksheet

Thinking

Weather reporters love to brag about their **Doppler** – or Super Doppler or NEXRAD – **radar** systems. Have you ever wondered what all the hype is about? Learn how the latest tools work: radar, satellite imaging and weather forecasting software (see the References section or search for weather forecasting technology on the Internet).

Writing

Imagine you are presenting the television weather report for the evening news (4-6PM). Prepare your script. Your report should include:

- Today's weather — local, state, national weather maps
- Record high and low temperatures
- Outlook for the evening
- Air quality report including pollution alerts and burning restrictions
- Tomorrow's prediction
- Five-day forecast
- Some interesting weather trivia or an explanation of a weather phenomenon

Create weather maps to use for your report. Make three maps, if possible: one for the local report (city and counties), one for a statewide report and one for the national report (often a satellite image). Make reusable symbols for high and low **fronts**, as well as cloud, sun, rain, snow and lightning symbols. What other props will you use? An umbrella? Raincoat? Sunglasses? Videotape your presentation if possible.

For extra credit, have students incorporate a lay person-level explanation of *Doppler effect* or *Doppler shift* as part of their in-class weather program presentation.

Vocabulary/Definitions

accurate: Exactly factual; errorless.

doppler radar: Radar that uses the Doppler effect to measure velocity of approaching weather.

forecast: To estimate or calculate in advance, especially to predict (weather conditions) by analysis of meteorological data.

front: Meteorology. The interface between air masses of different temperatures or densities.

satellite imagery: Pictures taken by photographic equipment mounted on satellites.

weathercast: A broadcast of weather conditions.

Assessment

Pre-Activity Assessment

Check to make sure students have completed their Weather Watcher Worksheets, both forecasts and actual data.

Activity Embedded Assessment

After introducing students to weather technology, use call-out questions or a pop quiz to reinforce vocabulary and understanding.

Post-Activity Assessment

Depending on the number of students in the class, a different student can deliver the weather forecast each day for a month and be assessed for presentation skills. The shared props for a "Weather Corner" — items such as maps, weather symbols and other graphic images — can be designed and assembled by the class.

Activity Scaling

Creating and presenting an in-class television weather program may be an individual or two-person activity.

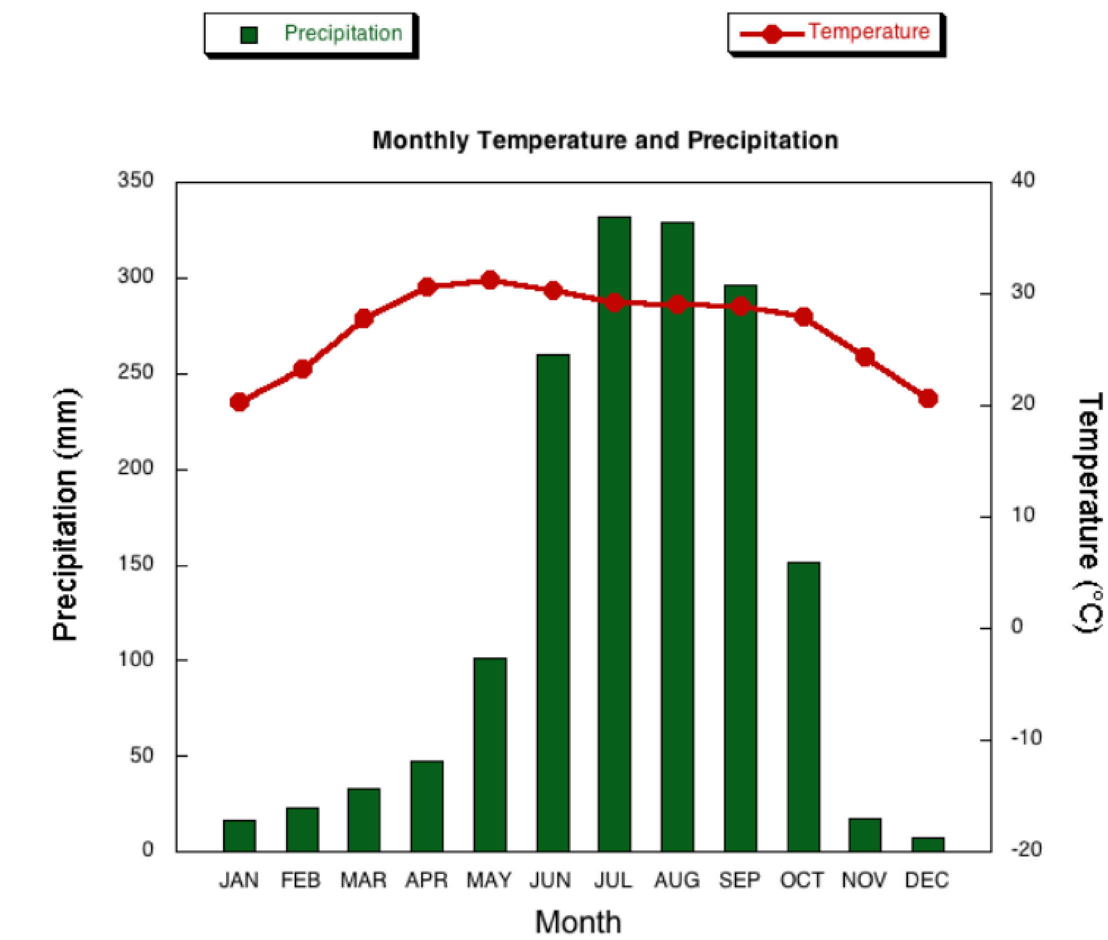
SEP-Asking questions and defining problems

CCC- Patterns

Resource- https://www.teachengineering.org/activities/view/cub_air_lesson05_activity3

3. World Climographs

   Description: Climographs show the average temperature and precipitation in an area over the course of the year. Websites like climatecharts.net can be used to quickly identify patterns of climate around the world. Students can also ask causation questions related to the climate differences (e.g. How do mountains and wind patterns affect the climate in an area?, How do large bodies of water affect the climate in an area?)



SEP- Analyze and Interpret Data

CCC- Patterns

Resource- https://thewonderofscience.com/phenomenon/2018/6/15/world-climographs

Universal Supports	Targeted Supports
• **Layer 1:** Review prior information about heat and cold- speed of movement of molecule, energy levels. Students will need to see examples of weather maps and the actual resulting weather, ex. high pressures and low pressure zones and their weather patterns. Students will need to see visuals and graphics of the different types of air	• **Layer 2:** Some students may need support in planning an investigation that helps to understand that when water vapor comes into contact with a cold glass (cause), the water vapor will become condensation (effect). Some students may also need help to understand the difference between

masses and their interactions and properties, ex. Cold masses have more density and less kinetic energy, when compared to warm masses. Students will read about causes of changes in weather, write down their thoughts about the reading, and then discuss their analysis in small groups.	weather and climate, ex. looking at climates zones vs. specific weather

Common Misconceptions

- Difficult to understand how high and low pressure zones interact and create weather like wind.
- Temperature changes do not play a huge role in weather.
- Wind has no mass and it is just there (magic...)
- The weather man chooses the weather based on a guess.
- Weather and climate are identical.
- The only water molecules in the atmosphere are visible (fog and clouds).

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

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The teacher could use these questions in science classroom discussions to bring out student's thoughts, ideas and cultures:

Validate-What knowledge and experiences have you had that might help us as a class explain what causes weather?
Ex. Students can express their experiences with weather and temperature changes and what they think caused them.

Affirm-What questions do we need to answer to test your ideas about what's happening with air masses of different temperatures?
Ex. Students will use their prior knowledge about weather causes to investigate how air masses contribute to weather changes.

Build & Bridge-Why does this phenomenon matter to you, to your community or others, and to scientists?
Ex. The teacher can ask why knowing about what causes changes in weather is important to your everyday life and the future?

Students who demonstrate understanding can:

MS-ESS2-6. **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. **ESS2.D: Weather and Climate** • Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. • The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Connections to other DCIs in this grade band:
MS.PS2.A ; **MS.PS3.B** ; **MS.PS4.B**

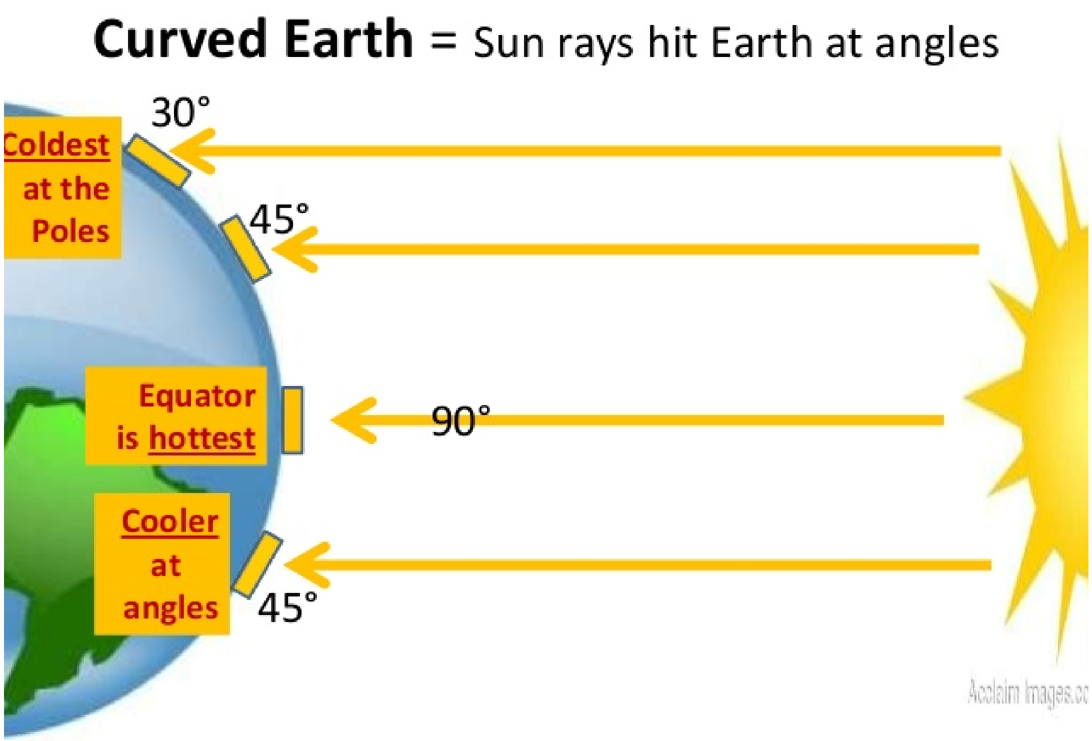
Articulation of DCIs across grade-bands:
3.PS2.A ; **3.ESS2.D** ; **5.ESS2.A** ; **HS.PS2.B** ; **HS.PS3.B** ; **HS.PS3.D** ; **HS.ESS1.B** ; **HS.ESS2.A** ; **HS.ESS2.D**

Common Core State Standards Connections:
ELA/Literacy -
SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. *(MS-ESS2-6)*

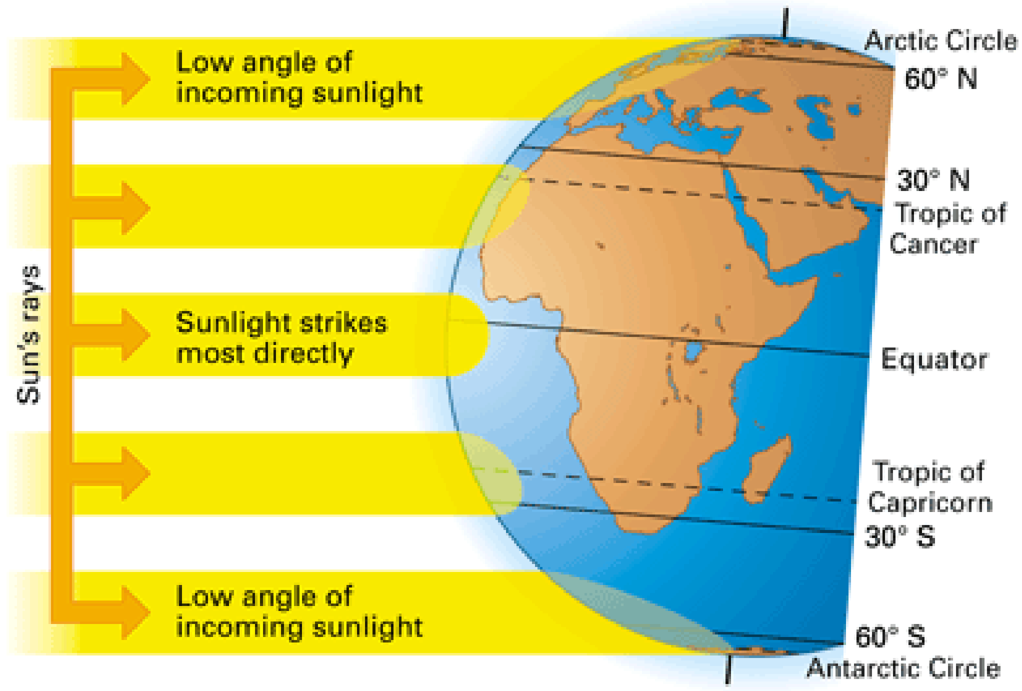
Grade	NGSS Discipline
MS	**[Earth Science 2.6](#)**
ESS2-6	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.* 1. Hot and Cold water/air masses create convection currents when they meet. a. Convection Tank: Have one mug of boiling water and one mug of ice. Place a tank filled with room temperature water on top of the two mugs. Put red food coloring at the bottom of the tank over the hot water mug and blue food coloring at the bottom of the tank over the cold water mud. Observe the convection currents and share out. (video of phenomenon- https://www.youtube.com/watch?v=PNz4drFlhVU) b. Convection Current Bottles: Fill 2 wide mouth bottles with hot water that is colored yellow, fill 2 wide mouth bottles with cold water that is colored blue. Using a playing card or stiff piece of paper, cover one cold bottle and flip over on top of a hot bottle. Remove the paper that is separating the water. Do the same with the other two bottles, but have the hot water on top and cold water on the bottom. Observe the convection currents and the difference when hot is on

top vs when cold is on top. (video of phenomenon- https://www.stevespanglerscience.com/lab/experiments/colorful-convection-currents/)

2. The Earth is not heated/cooled evenly by the sun.
   a.



   b.



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.

Modeling the Coriolis Effect

The Coriolis effect is named after Gustave Gaspard Coriolis, a 19th-century French professor of mechanical engineering. He calculated much of the mathematics behind the effect. The theory explains the apparent deviation in the path of winds and water currents across the earth. Although Coriolis' interest was in the various forces acting upon rotating pieces of machinery, the Coriolis effect is a topic in earth, environmental, and marine science. The effect can be a tough concept to explain, but it is fairly easy to model. The phenomenon can be demonstrated with a simple and inexpensive balloon activity.

Because the earth rotates (from west to east around a north-south axis), paths of objects moving great distances across the earth's surface are deflected. If a plane left the North Pole, flying south toward Portland, Maine, and maintained that straight-line path for a period of time, the pilot might actually land in Portland, Oregon instead. From the perspective of a person standing in Portland, Maine, who had somehow been able to watch the entire flight, the plane would have veered far to the west, or to the right of the straight path, as seen from the North Pole. Similarly, both Anchorage and Los Angeles rotate once in a 24-hour day. Los Angeles "travels" farther and faster in that time period because it is on a lower latitude. Students need to picture this phenomenon clearly before they can comprehend the Coriolis effect and its impact on weather systems and ocean currents.

This activity takes approximately 15 minutes to complete. You can assess student understanding with the questions and answers provided. The extension activities introduce the meteorological and oceanographic applications of the activity.

Materials (per each student pair)

- 1 Balloon (round)
- 2 Permanent Markers (different colors; visible when applied to balloons)

Preparation

1. Divide the class into working pairs.
2. Provide each pair with a balloon and 2 markers.
3. Project the questions on your board so that the students can answer them as they work (optional).

Procedure

1. Blow up a balloon.
2. With a marker, draw the equator on the balloon midway between the knot and the top of the balloon. Label the top North Pole and the knot South Pole.
3. Hold the balloon at eye level, by the knot, and rotate it left to right, simulating the rotation of the earth.
4. While 1 partner rotates the earth balloon, the other examines the movement of the earth from the North Pole perspective and from the South Pole perspective. Answer questions 1 and 2.
5. While 1 partner continues to rotate the balloon steadily from left to right, the other slowly tries to draw a line straight from the North Pole, south to the equator, using a second marker. While the earth continues to rotate, 1 partner tries to draw a straight line from the South Pole, north to the equator. Answer questions 3 and 4.

Students may struggle with understanding that the direction of the earth's movement is based on their point of view. When they describe the direction (left or right) that the "straight" lines veer, make sure that the students determine this direction from the perspective of the beginning point of the line. Take a few minutes to discuss this as a class. You may also address common misconceptions concerning the Coriolis effect, such as the notion that the direction of swirl in a flushing toilet differs in the northern and southern hemispheres.

Extension Activities

- Have students relate the directional movement of large air masses, ocean currents, and hurricanes to the Coriolis effect. They may find maps that depict the prevailing winds and ocean currents in the northern and southern hemispheres.
- Change the rotational speed of the balloon and compare the amount of "curve" between a slow and fast rotation.
- If you have access to a merry-go-round, have some students sit at various points on the perimeter and face the center. While someone spins the merry-go-round, have a student on the merry-go-round try to roll a ball straight toward the person directly across from him/her.

Vary the speed and rotation of the merry-go-round, as well as the speed of the ball, and discuss any differences. Have students relate this demonstration to the Coriolis effect. If you do not have access to a merry-go-round, you can conduct similar demonstrations using a turntable and marbles, but without the perspective of someone actually on the rotating object.

Questions and answers

1. As you look from the North Pole toward the equator, is the balloon spinning clockwise or counterclockwise?
   The balloon appears to be spinning counterclockwise.
2. As you look from the South Pole toward the equator, is the balloon spinning clockwise or counterclockwise?
   The balloon appears to be spinning clockwise.
3. What happened when you tried to draw a straight line from the North Pole to the equator?
   The line was not straight but instead veered west or right of the intended path.
4. What happened when you tried to draw a straight line from the South Pole to the equator?
   The line was not straight but instead veered west or left of the intended path.
5. Predict what would happen if you again drew lines in the northern and southern hemispheres but with the earth rotating in the opposite direction.
   The curving of the objects in the northern and southern hemispheres would be reversed. Objects moving from the North Pole to the equator would veer to the left of their path and objects moving from the South Pole toward the equator would veer to the right of their path (toward the east, in both cases).

SEP- Develop and Using Models
CCC- Cause and Effect
Resource-
https://www.carolina.com/teacher-resources/Interactive/modeling-the-coriolis-effect/tr10643.tr

Universal Supports	Targeted Supports
• **Layer 1:** Students will need to see a visual demonstration of the atmospheric and oceanic circulation, ex. convection currents. Students will need to see a model or demonstration of how the Sun hits different parts of the Earth in varying intensity causing the uneven heating, ex. tilted globe with a flashlight. Students can work together in small groups with the convection current models to learn about how hot and cold air/water masses interact. Finally, students should study the different Biomes around the world and analyze the different climates on Earth and relate them to uneven heating.	• **Layer 2:** Some students may need extra support in modeling the system of uneven heating and how it creates the different climates around the world, ex. looking at a climate map and noting the areas that are the same and those that are different and help them draw conclusions of why that might be.

Common Misconceptions

- Students think that the Earth is not on a tilt, it just rotates on its axis at a 180 degree angle.
- Maps and globes are not related.
- The shape of the Earth does not contribute to unequal heating.
- All climates are basically the same.
- Small climate changes only have small impacts.
- Human activity does not affect climate.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

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Validate-What knowledge and experiences have you had that might help us as a class explain what contributes to different climates?
Ex. Students can share their experiences in other climates and can hypothesize what causes them to be so different from our climate in New Mexico.

Affirm-What questions do we need to answer to test your ideas about what's happening with unequal heating of the Earth and its impact on climate?
Ex. Students can plot their experiences with other climates on a map and analyze the location in terms of heating and compare it to their current location. Students can also look at their hypotheses and determine how they are related to uneven heating.

Build & Bridge-Why does this phenomenon matter to you, to your community or others, and to scientists?
Ex. The teacher can ask how does climate impact your daily life and how does that compare to other parts of the world?

Section 3: Resources

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

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

Engaging in the Practices of Science

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Crosscutting concepts

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

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

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

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

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

Planning Guidance for Culturally and Linguistically Responsive Instruction

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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