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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.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 following²:

- 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.

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

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

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

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

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

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

teacher facilitation, students can become dissatisfied with what they believe they already know and strive to understand it in the context of the DCI that the teacher is targeting.³

Classroom Assessment Items

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

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

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

- Measuring the three-dimensional science learning called for in the framework and the NGSS requires assessment tasks that examine students' performance of scientific and engineering practices in the context of crosscutting concepts and disciplinary core ideas. To adequately cover the three dimensions, assessment tasks will generally need to contain multiple components. It may be useful to focus on individual practices, core ideas, or crosscutting concepts in the various components of an assessment task, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given performance expectation.
- The Next Generation Science Standards require that assessment tasks be designed so they can accurately locate students along a sequence of progressively more complex understandings of a core idea and successively more sophisticated applications of practices and crosscutting concepts.
- The NGSS places significant demands on science learning at every grade level. It will not be feasible to assess all the performance expectations for a given grade level with any one assessment. Students will

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

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 Tools⁶:

- 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:

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

[From Molecules to Organisms: Structures and Processes](#)

[LS-4-1](#)

[LS-4-2](#)

[LS-4-3](#)

[LS-4-4](#)

[LS-4-5](#)

[LS-4-6](#)

Students who demonstrate understanding can:

MS-LS4- Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

1. [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]

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. <ul style="list-style-type: none"> Analyze and interpret data to determine similarities and differences in findings. <p><i>Connections to Nature of Science</i></p> Scientific Knowledge is Based on Empirical Evidence <ul style="list-style-type: none"> Science knowledge is based upon logical and conceptual connections between evidence and explanations. 	LS4.A: Evidence of Common Ancestry and Diversity <ul style="list-style-type: none"> The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. 	Patterns <ul style="list-style-type: none"> Graphs, charts, and images can be used to identify patterns in data. <p><i>Connections to Nature of Science</i></p> Scientific Knowledge Assumes an Order and Consistency in Natural Systems <ul style="list-style-type: none"> Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Connections to other DCIs in this grade-band:

MS.ESS1.C ; MS.ESS2.B

Articulation of DCIs across grade-bands:

3.LS4.A ; HS.LS4.A ; HS.ESS1.C

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-LS4-1)
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-LS4-1)

Mathematics -

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-LS4-1)

Grade	NGSS Discipline
MS	<u>Life Science 4.1</u>
LS4-1	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.

Students work as paleontologists where they discover a mystery fossil. Through the use of the fossil record, students must determine where to place the mystery fossil amongst other fossilized organisms.[Farin Finds a Fossil](#)

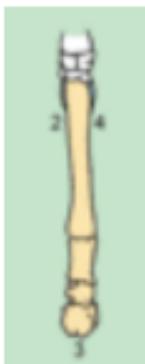
Classroom Assessment Items

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.

Sample Assessment:

- You are a paleontologist working at the Museum of Natural History. A farmer from Schuylerville, NY brings you a tooth and leg bone he found when removing rocks from a field. You believe these bones are from an extinct species that is an ancestor of the horse.
- Examine the fossils and data provided below. Your job is to find patterns and to determine the relative age of the fossils.

Here are the pictures of the fossils the farmer found (not to scale):



Foreleg



Tooth

- [Ancient Horse Fossil](#)

Universal Supports

- **Layer 1:** Introduce the fossil record. Provide students with visual and written samples of the fossil record. Use the “I do, we do, you do” strategy using the fossil record for students to determine similarities and differences in the fossil record and identifying patterns. Allow students to practice in small groups with organizing given data to place fossils in chronological order as well as identification of emerging organisms, extinction, and evolution.

Targeted Supports

- **Layer 2:** Small group work with students to help them identify patterns within the fossil record by interpreting data to show emergence, extinction, and evolution.

	<p>Have students practice on their own while the teacher is walking around the room and providing support.</p> <h2>Common Misconceptions</h2> <ul style="list-style-type: none"> • Extinction is rare. • Most of the species that lived in the past are still alive today. • Anatomical change occurs quickly. • There has always been great diversity and complexity of life on Earth. • Evolution is only about the origin of life. • The word “theory.” In everyday language, the word <i>theory</i> can be used to describe an initial idea without supporting evidence vs in science where the word <i>theory</i> is a well-tested explanation for observations in the natural world. • The fossil record is complete. <h2>Culturally and Linguistically Responsive Instruction</h2> <h3>Guiding Questions and Connections</h3> <p>These questions are for sense making circles. Use these questions to help guide a class discussion that brings student's own thoughts and ideas into the science classroom.</p> <p>Validate and Affirm:</p> <ul style="list-style-type: none"> • What animals do you know that are extinct? • What animals are fossilized? <p>Build and Bridge:</p> <ul style="list-style-type: none"> • What knowledge and experiences have you had that might help us as a class explain the existence, diversity, extinction, and change of life forms throughout the history of life on Earth? • What questions do we need to answer to test your ideas about what's happening in the fossil record? • Why does this phenomenon matter to you, to your community or others to scientists?
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Students who demonstrate understanding can:

- MS-LS4-2.** Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]

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. <ul style="list-style-type: none"> Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. 	LS4.A: Evidence of Common Ancestry and Diversity <ul style="list-style-type: none"> Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. 	Patterns <ul style="list-style-type: none"> Patterns can be used to identify cause and effect relationships. <hr/> Connections to Nature of Science Scientific Knowledge Assumes an Order and Consistency in Natural Systems <ul style="list-style-type: none"> Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Connections to other DCIs in this grade-band:

MS.LS3.A ; MS.LS3.B ; MS.ESS1.C

Articulation of DCIs across grade-bands:

3.LS4.A ; HS.LS4.A ; HS.ESS1.C

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-LS4-2)
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-LS4-2)

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-LS4-2)
SL.8.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. (MS-LS4-2)

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (MS-LS4-2)

Mathematics -

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-LS4-2)

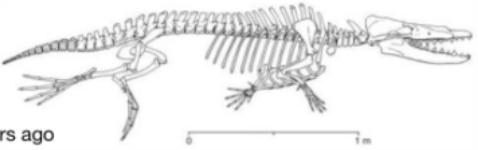
Grade	NGSS Discipline
MS	Life Science 4.2
LS4-2	<h2>Sample Phenomena</h2> <p><i>When available, you should use your locally selected or created high quality instructional materials. However, the following is an example phenomenon you can use if you don't have local instructional materials available.</i></p> <p>Sample Phenomenon #1:</p> <p>Whales have more anatomical similarities with humans than with sharks.</p> <h2>Classroom Assessment Items</h2> <p><i>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.</i></p>

Sample Assessment:

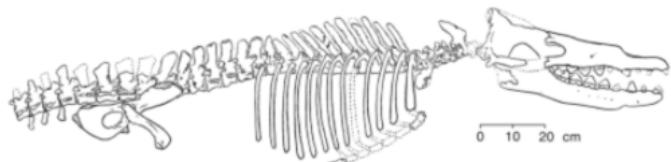
These fossils of an extinct mammal were discovered by paleontologists in Pakistan in 1994. Make a claim as to which **extant** (currently surviving) mammal is most related to this extinct mammal. The most common orders of mammals along with skeletons are listed on the next three pages.

Find # E

Location: Pakistan
Date found: 1994
Age of Rock: 46 million years ago



- Write a claim for the current order of mammal that is most related to this extinct fossil.
 - Support your claim with data from the patterns of anatomical similarities and differences between the modern and fossil organisms.
 - Share your reasoning
- [A Fossilized Mammal](#)



Sample Assessment #2:

[California Tapir](#)

Universal Supports

- **Layer 1:** Have students look at various bone structures of different organisms. Allow them to color in homologous structures that they see by identifying patterns. Let students compare and contrast within their small groups or with a partner. As a whole group, determine what structures are homologous. Similarities at the microscopic level: DNA. Case study to determine if a panda is a bear or racoon. ([A Tale of Two Pandas](#))

Targeted Supports

- **Layer 2:** Small groups to look for patterns of anatomical similarities amongst multiple organisms (past and present).

Common Misconceptions

- Species that are similar can share a common ancestor, but species that have no apparent, obvious, or superficial similarities cannot share a common ancestor.
- Plants and animals cannot share a common ancestor.
- Humans do not share a common ancestor with other living organisms.
- Humans came from monkeys.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

These questions are for sense making circles. Use these questions to help guide a class discussion that brings student's own thoughts and ideas into the science classroom.

Validate and Affirm:

- What animals are similar and different from each other using the animals you know?
- What animals do you know of living today that are similar to extinct animals?

Build and Bridge:

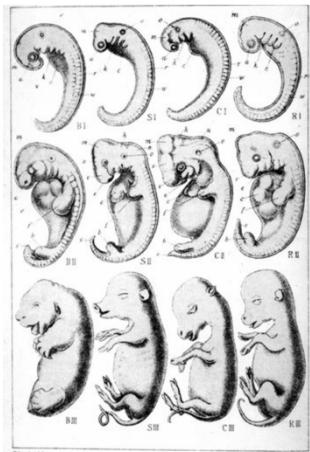
- What knowledge and experiences have you had that might help us as a class explain how animals can be distantly related to each other?
- What questions do we need to answer to test your ideas about how these animals could be related?
- Why does this phenomenon matter to you, to your community or others to scientists?

Students who demonstrate understanding can:

- MS-LS4-3. Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy. [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]

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. <ul style="list-style-type: none"> Analyze displays of data to identify linear and nonlinear relationships. 	LS4.A: Evidence of Common Ancestry and Diversity <ul style="list-style-type: none"> Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. 	Patterns <ul style="list-style-type: none"> Graphs, charts, and images can be used to identify patterns in data.
Connections to other DCIs in this grade-band: N/A		
Articulation of DCIs across grade-bands: HS.LS4.A		
Common Core State Standards Connections: ELA/Literacy - RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-LS4-3) 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-LS4-3)		
Grade	<i>NGSS Discipline</i>	
MS	Life Science 4.3	
LS4-3	Sample Phenomena	
	<i>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.</i> Sample Phenomenon #1: Chickens and cows have embryological similarities but they are two different organisms.	
	Classroom Assessment Items	
	<i>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.</i>	



Sample Assessment:

The drawings below show the development of an opossum, pig, goat, and ox.
[\(source\)](#)

Analyze the pictures to determine which two organisms are most closely related to each other. You must include a **claim**, **evidence** and **reasoning** in your explanation.

[Evidence of Common Ancestry and Diversity](#)

Universal Supports

- **Layer 1:** Introduce students to embryos. Have students identify similarities and differences between different embryos. Scrambled embryo, where students are given five different organisms at three different embryo stages. They will need to organize the embryos under the correct organism and stage.

Targeted Supports

- **Layer 2:** Small group to further support students with identifying patterns to determine similarities of embryological development using the example of whale embryos and land animals looking at their hind limbs.

Common Misconceptions

- Embryos of different species always look very different.
- Embryos of a single species look the same at every stage.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

These questions are for sense making circles. Use these questions to help guide a class discussion that brings student's own thoughts and ideas into the science classroom.

Validate and Affirm:

- What knowledge and experiences have you had that might help us as a class explain how babies are formed inside a womb or egg?

Build and Bridge:

- What questions do we need to answer to test your ideas about the similarities and differences of embryos?
- Why does this phenomenon matter to you, to your community or others to scientists?

Students who demonstrate understanding can:

- MS-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

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. <ul style="list-style-type: none"> Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena. 	LS4.B: Natural Selection <ul style="list-style-type: none"> Natural selection leads to the predominance of certain traits in a population, and the suppression of others. 	Cause and Effect <ul style="list-style-type: none"> Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Connections to other DCIs in this grade-band:

MS.LS2.A ; MS.LS3.A ; MS.LS3.B

Articulation of DCIs across grade-bands:

3.LS3.B ; 3.LS4.B ; HS.LS2.A ; HS.LS3.B ; HS.LS4.B ; HS.LS4.C

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (*MS-LS4-4*)
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-LS4-4*)

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-LS4-4*)

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (*MS-LS4-4*)

SL.8.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. (*MS-LS4-4*)

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (*MS-LS4-4*)

Mathematics -

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (*MS-LS4-4*)

6.SP.B.5 Summarize numerical data sets in relation to their context. (*MS-LS4-4*)

7.RP.A.2 Recognize and represent proportional relationships between quantities. (*MS-LS4-4*)

Grade	NGSS Discipline
MS	<u>Life Science 4.4</u>
LS4-4	<h2>Sample Phenomena</h2> <p><i>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.</i></p> <p>Sample Phenomenon #1:</p> <p>The Valley of Fires is located in southeastern New Mexico, just outside of Carrizozo. The Valley of Fires is one of the youngest lava flows in the United States. Here, prior to the volcanic eruption, the rock pocket mice were dominantly light colored but after the volcanic eruption, the rock pocket mice have become dominantly dark colored.</p> <p>Video: Natural Selection and Rock Pocket Mouse</p>

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.

Assessment Sample: Most scientists think that a small group of finches colonized the Galápagos Islands thousands of years ago. They would have been the only seed-eating birds on the islands. Suppose one island was very dry and another had plentiful rainfall.

Data Set C - Galapagos Islands Finch - 25cm Average Rainfall



How would the finch populations on these islands change over time?

Galapagos Islands Finches

Universal Supports

Targeted Supports

- Layer 1:** Discuss similarities and differences between a specific type of species and its environment. (Ex. Finches on Galapagos Islands, Turtle on Galapagos Islands) Discuss what determines an organism's ability to survive.

- Layer 2:** Take a specific organism and identify why they survived and passed on their trait(s) to the next generation.

Common Misconceptions

- Individual organisms can change their features to suit the environment.
- All individuals of the same species have the same features.
- Natural selection occurs within an organism's lifetime.
- All organisms in a population are able to adapt to environmental changes and survive.
- Offspring have more adaptive traits than their offspring.
- Natural Selection means "survival of the fittest."

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

These questions are for sense making circles. Use these questions to help guide a class discussion that brings student's own thoughts and ideas into the science classroom.

Validate and Affirm:

- What are some traits in your environment that allow animals to survive?
- What knowledge and experiences have you had that might help us as a class explain what's happening and how some traits increase the probability of surviving?

What questions do we need to answer to test your ideas about the traits that help us survive?

Build and Bridge

- What questions do we need to answer to test your ideas about the traits that help us survive?
- Why does this phenomenon matter to you, to your community or others to scientists?

Students who demonstrate understanding can:

5. **Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.** [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.]

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
<p>Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods.</p> <ul style="list-style-type: none"> Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. 	<p>LS4.B: Natural Selection</p> <ul style="list-style-type: none"> In <i>artificial</i> selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. <p>Connections to Engineering, Technology, and Applications of Science</p> <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. <p>Connections to Nature of Science</p> <p>Science Addresses Questions About the Natural and Material World</p> <ul style="list-style-type: none"> Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

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

Articulation of DCIs across grade-bands:
HS.LS3.B ; HS.LS4.C

Common Core State Standards Connections:

ELA/Literacy -

- RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-LS4-5)
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-LS4-5)

Grade	NGSS Discipline
MS	Life Science 4.5
LS4-5	<h2>Sample Phenomena</h2> <p><i>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.</i></p> <p>Sample Phenomenon #1: CRISPR-Cas9 is a type of gene editing that may be able to cure thousands of genetic diseases. CRISPR Simulation</p> <p>Sample Phenomenon #2: GMOs vs Organic Foods</p>

[Agricultural Literacy](#)

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.

Assessment Sample #1:

How is technology impacting the growing need of genetically modified turkeys?

[GMO vs Organic](#)

Assessment Sample #2:

Genetically Modified Foods... Do the benefits outweigh the safety concerns?

Do the benefits of genetically modified organisms used by the food industry outweigh the possible safety concerns? After reading informational texts, write an editorial for "The New York Times Learning Blog" in which you address the question and argue whether genetically modified organisms are valuable or detrimental to society. Support your position with evidence from the text(s). Be sure to acknowledge competing views. Give at least one example/s from past or current events to illustrate and clarify your position.

[Genetically Modified Foods](#)

Universal Supports

- Layer 1:** Using an example, such as dog breeds, how do humans artificially select traits?
Cabbage, brussel sprouts, kale, broccoli, and cauliflower are all artificial selection from the plant.

Targeted Supports

- Layer 2:** Begin by displaying a source (text, media, visual, display, data, etc.) for all students to view. Teach students how to identify a resource that is credible with guidance of a checklist (see examples below). Have students work together in small groups to identify credible resources. Have students practice on their own to gather and synthesize information on sensory receptors.

Web Page Credibility Checklist

Use this checklist as a guideline to help you decide whether an online source is reliable.
7 or more points: This is probably a reliable source; consider using it.
4-6 points: This might be a good source; try to find out more about it before using it.
3 or less: This is probably not worth including in your sources.

URL: http://	Circle the number in the column that is the best answer	Yes	No/Not Sure
	POSITIVES		
I can identify a group or individual responsible for the content on this site.	1	0	
This site was created by a person or organization that I know is credible outside of the Internet.	1	0	
This site has been updated in the past 3 to 6 months.	1	0	
This site has external links to other credible websites.	1	0	
I know of other credible websites that link to this website.	1	0	
This site has a .gov or .edu suffix.	1	0	
This site provides a phone number or mailing address that I could use for contact with the author or organization for more information.	1	0	
I have verified the information on this site using reliable offline resources.	1	0	
The main purpose of this site is to provide facts (not opinions).	1	0	
subtotal:			
NEGATIVES			
This site is clearly biased toward a specific opinion or point of view.	-1	0	
This site contains many misspellings and/or broken links.	-1	0	
The main purpose of this site is to sell a product or service.	-1	0	
This site has no external links.	-1	0	
final total:			
Would you use this as a credible source? Why or why not?			

[Taken from page 11](#)

[Website Credibility Checklist](#)

Small group instruction on explicit interventions for understanding how to gather and synthesize information from various sources assessing credibility and accuracy.

Common Misconceptions

- Artificial selection is bad for organisms.
- Natural selection is a directed process rather than a random one.
- Selection against a species means the species will become extinct.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

These questions are for sense making circles. Use these questions to help guide a class discussion that brings student's own thoughts and ideas into the science classroom.

Validate and Affirm:

- What organisms do you know of that have changed because of humans?
- Do you know any roles humans play in changing an organism?

Build and Bridge:

- What knowledge and experiences have you had about artificial selection?
- What questions do we need to answer to test your ideas about how humans have influenced certain characteristics of organisms through selective breeding?
- Why does this phenomenon matter to you, to your community or others to scientists?

Students who demonstrate understanding can:

- MS-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. <ul style="list-style-type: none"> Use mathematical representations to support scientific conclusions and design solutions. 	LS4.C: Adaptation <ul style="list-style-type: none"> Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. 	Cause and Effect <ul style="list-style-type: none"> Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Connections to other DCIs in this grade-band:

MS.LS2.A ; MS.LS2.C ; MS.LS3.B ; MS.ESS1.C

Articulation of DCIs across grade-bands:

3.LS4.C ; HS.LS2.A ; HS.LS2.C ; HS.LS3.B ; HS.LS4.B ; HS.LS4.C

Common Core State Standards Connections:

Mathematics -

MP.4 Model with mathematics. (MS-LS4-6)

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-LS4-6)

6.SP.B.5 Summarize numerical data sets in relation to their context. (MS-LS4-6)

7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-LS4-6)

Grade	NGSS Discipline
MS	Life Science 4.6
LS4-6	<h2>Sample Phenomena</h2> <p>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.</p> <p>Sample Phenomenon #1: Charles Darwin's Finches on Galapagos Island were identical to mainland finches but had different beaks.</p> <p>Sample Phenomenon #2: Bunny population increases or decreases depending on if the trait supports survival and reproduction. Natural Selection phet simulation</p> <p>Sample Phenomenon #3: The African savanna elephant population is declining due to poaching. Analyzing Data on Tuskless Elephants</p> <h2>Classroom Assessment Items</h2> <p>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.</p>

Assessment #1:

Most scientists think that a small group of finches colonized the Galápagos Islands thousands of years ago. They would have been the only seed-eating birds on the islands. Suppose one island was very dry and another had plentiful rainfall.

Data Set C - Galapagos Islands Finch - 25cm Average Rainfall



How would the finch populations on these islands change over time?

[Galapagos Islands Finches](#)

Universal Supports

Targeted Supports

- Layer 1:** Discuss similarities and differences between a specific type of species and its environment. Use data tables to show how the populations changed over time and may continue to change. (Ex. Finches on Galapagos Islands, Turtle on Galapagos Islands) Discuss what determines an organism's ability to survive.

- Layer 2:** Take a specific organism and identify why they survived and passed on their trait(s) to the next generation.

Common Misconceptions

- Organisms can change their features to suit their environment.
- Animals of the same species all have the same features.
- Natural selection occurs within an organism's lifetime.
- "Survival of the fittest" means the strongest individuals survive.
- Natural selection is goal-oriented.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

These questions are for sense making circles. Use these questions to help guide a class discussion that brings student's own thoughts and ideas into the science classroom.

Validate and Affirm:

- What are some things happening that could cause animals to disappear?
- What knowledge and experiences have you had about the changing of organisms in our world?

Build and Bridge:

- What questions do we need to answer to test your ideas about how organisms experienced changes of a specific trait in a population?
- Why does this phenomenon matter to you, to your community or others to scientists?

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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Crosscutting concepts

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

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

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

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

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

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

Planning Guidance for Culturally and Linguistically Responsive Instruction

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

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

Validate/Affirm: How can you design your classroom to intentionally and purposefully legitimize the home culture and languages of students and reverse the negative stereotypes regarding the science abilities of students of marginalized cultures and languages?

Build/Bridge: How can you create connections between the cultural and linguistic behaviors of your students' home culture and language and the culture and language of school science to support students in creating identities as capable scientists that can use science within school and society?

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

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

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

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

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

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

Inequities are built into the systems of science education such that "students of color, students who speak first languages other than English, and students from low-income communities... have had limited access to high-quality, meaningful opportunities to learn science." Intersecting equity projects can guide the teaching and learning of science towards social justice. Science educators who engage in these projects help advance Indigenous

self-determination (details) and racial justice by confronting the consequences of legacies of injustice and promoting liberatory approaches to education.

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

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

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

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

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

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

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

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

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

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