NEW MEXICO
Public Education Department

New Mexico Instructional Scope
HS Life Science Guide

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Public Education Department

New Mexico STEM Ready! Science Standards Implementation Guide

Overview

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

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

The standards

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

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

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

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

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

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

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

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

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

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

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

Sample Phenomena

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

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

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

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/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

Biology Evolution: Unity and Diversity
HS-LS4-1
HS-LS4-2
HS-LS4-3
HS-LS4-4
HS-LS4-5
HS-LS4-6

Students who demonstrate understanding can:

HS-LS4-1. **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.** [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of 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
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). - - - - - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	**LS4.A: Evidence of Common Ancestry and Diversity** • Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. - - - - - ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.

Connections to other DCIs in this grade-band:
HS.LS3.A ; **HS.LS3.B** ; **HS.ESS1.C**

Articulation of DCIs across grade-bands:
LS3.A ; **LS3.B** ; **MS.LS4.A** ; **MS.ESS1.C**

Common Core State Standards Connections:
ELA/Literacy -
RST-11.12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-LS4-1)*
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-LS4-1)*
WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. *(HS-LS4-1)*
SL.11-12.4 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. *(HS-LS4-1)*
Mathematics -
MP.2 Reason abstractly and quantitatively. *(HS-LS4-1)*

Grade	*NGSS Discipline*

HS — Life Science 4.1

Sample Phenomena

LS4-1

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.

CLASSIFYING BIRDS IN THE UNITED STATES (SPECIES CONCEPT)

Modern biological classification schemes generally contain a number of categories, each representing a group of organisms with a particular degree, or level, of relatedness to one another. Organisms that have the greatest number of shared characteristics are grouped together in the category of species. However, as important as the concept of a species is, the category itself is sometimes hard to define in practice. The following task is an example of this problem. Figures 1.1–1.10 show 10 different birds that were recently observed in different parts of the United States.

Figure 1.1. Bird A Figure 1.2. Bird B Figure 1.3

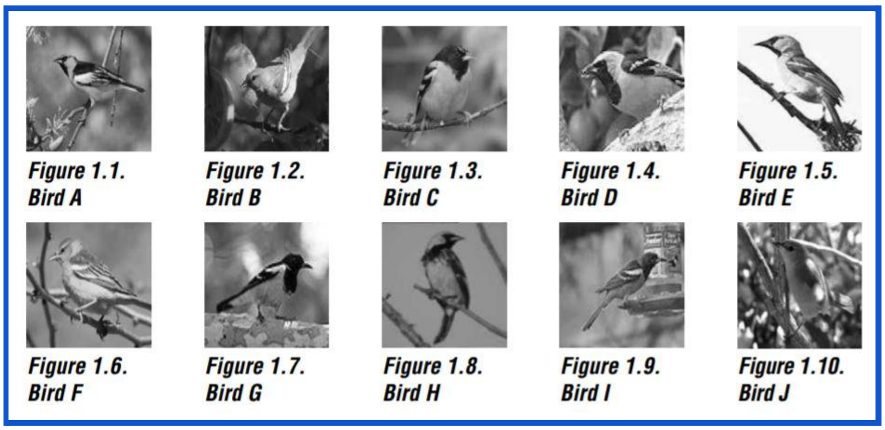


Figure 1.1. Bird A *Figure 1.2. Bird B* *Figure 1.3. Bird C* *Figure 1.4. Bird D* *Figure 1.5. Bird E*
Figure 1.6. Bird F *Figure 1.7. Bird G* *Figure 1.8. Bird H* *Figure 1.9. Bird I* *Figure 1.10. Bird J*

All of these birds have very similar body shapes and coloration, but each one has a unique set of physical characteristics that can be used to distinguish it from the others (see Table 1.1, p. 7). As a result, some people think that these 10 birds represent 10 different species, while others think that these 10 birds represent one species consisting of many different varieties. This has made many people wonder: **How many species do these 10 different birds represent?**

With your group, develop a claim that best answers this question. Once your group has developed your claim, prepare a whiteboard that you can use to share and justify your ideas. Your whiteboard should include all the information shown in the diagram on Figure 1.11.

- ***Galapagos Finch Evolution (Video)***

When Darwin visited the Galapagos Island he collected a number of bird species that he brought back to England. He presented them to ornithologist John Gould thinking they were a variety of birds and he was told that they were all different varieties of finches. This led Darwin to speculate that a population of finches had arrived on the islands and had adapted to different climates through natural selection. However Darwin was never able to observe evolution taking place. Researchers Peter and Rosemary Grant have been observing evolution of Galapagos finches for the last 40 years. One of the most famous studies involved the change in beak depth of medium ground finches during times of drought. Birds that had small beaks were unable to open the dry seeds causing microevolution in the surviving birds.

Web Resources:

- [Galapagos Finch Evolution — The Wonder of Science]
- [Peter and Rosemary Grant]

- ***Hox Genes (Video)***

Hox genes control the body plan of organisms with each hox gene coding for a specific body part. Hox gene mutations (e.g. a fruit fly with a leg in the place of an antenna) can lead to investigations on development. Similarities in hox genes across various animals can show phylogeny.

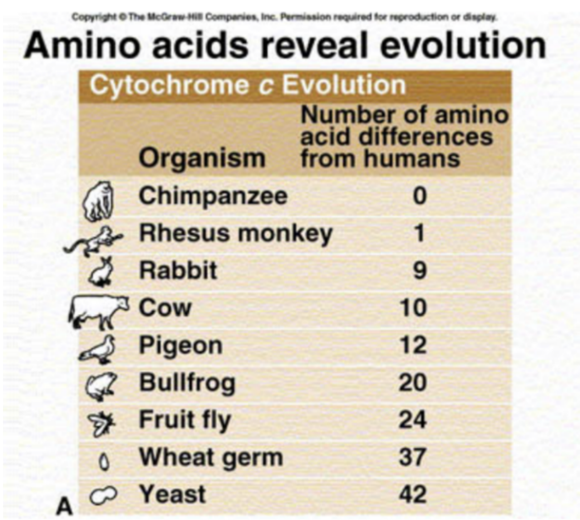
Web Resource:

- **Hox Genes — The Wonder of Science**

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.

Cytochrome C is an enzyme that is responsible for helping synthesize ATP which supplies all the energy for living organisms.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Amino acids reveal evolution

Cytochrome *c* Evolution	
Organism	Number of amino acid differences from humans
Chimpanzee	0
Rhesus monkey	1
Rabbit	9
Cow	10
Pigeon	12
Bullfrog	20
Fruit fly	24
Wheat germ	37
Yeast	42

A

A. Use the image above and your knowledge of appropriate terms to explain why the image is evidence for the idea of evolution.
B. If you tested for the sequence of cytochrome C from a mosquito what would you expect to find?

HS-LS4-1 Assessment - Cytochrome C

Universal Supports	Targeted Supports

I know the word and use the word	I know the word but don't use it	I have heard the word, but I'm not sure what it means	I have never heard the word

- Review and exercise vocabulary where the teacher provides a set of words from the unit and students identify the words following the guide below: (Ex. anatomy, ancestor, evidence. etc.)
- Provide a video or reading samples that would introduce evidence of common ancestry to students in an engaging way, by asking them to identify bones while noticing details and wondering about the implications and become curious, ask questions, bring background knowledge to bear, and make hypotheses in a similar way to what Darwin and others must have done when they noticed similarities between bone structures.
- Project images for students to analyze. (Ex: images of the evolution of the theropod foot and the foot development of an embryonic bird)
- Utilize a science notebook and have students to document the following information in their notebook:
  - similarities between the images
  - patterns they recognize
  - if these images support the idea that birds evolved from theropod dinosaurs and explaining why or why not

- Group students together according to their difficulties (Vocabulary, Classification, etc.) and provide necessary materials for reinforcement and individual teacher support
- Provide extended time to accomplish task and individual tutoring

Common Misconceptions

- Taxa that are adjacent on the tips of phylogeny are more closely related to one another than they are to taxa on more distant tips of the phylogeny.
- Taxa that are nearer the bottom or left-hand side of a phylogeny represent the ancestors of the other organisms on the tree.
- Taxa that are nearer the bottom or left-hand side of a phylogeny evolved earlier than other taxa on the tree.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

	Students bring in a special item from home that they share with class to learn about one's and each other's backgrounds. Empower students' sense of identity, background, and uniqueness by sharing a piece of their family's cultural heritage. ● Some questions to start off the unit: ● What makes you special? ● What makes you unique from your classmates? ● Identify on a world map the countries from which their families originated ● Understand that immigrants from all over the world come to the United States to start new lives ● Understand that family history and background helps students better understand their heritage, customs, and family values. It also helps them understand the role of your culture's roots in shaping American culture. ● Consider checking with parents or guardians to discuss the activity and to find out if they have concerns about a 'personal history' activity. There may be sensitivities in families with non-traditional configurations, adopted children, those in which children are living in foster care or those with ancestors who were forcibly brought to this country, in which case students might not know historical information about their families.

Students who demonstrate understanding can:

HS-LS4-2. **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [*Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS4.B: Natural Selection** • Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. **LS4.C: Adaptation** • Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-band:
HS.LS2.A ; **HS.LS2.D** ; **HS.LS3.B** ; **HS.ESS2.E** ; **HS.ESS3.A**

Articulation of DCIs across grade-bands:
MS.LS2.A ; **LS3.B** ; **MS.LS4.B** ; **MS.LS4.C**

Common Core State Standards Connections:
ELA/Literacy -

RST-11.12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS4-2)
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS4-2)
WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS4-2)
SL.11-12.4 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. *(HS-LS4-2)*

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-LS4-2)
MP.4 Model with mathematics. *(HS-LS4-2)*

Grade	*NGSS Discipline*
HS	**Life Science 4.2**
LS4-2	**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.* **Tuskless Elephants** The Mozambique civil war lasted between 1992-1997. Ninety percent of the elephant population in Mozambique were killed for their ivory or meat to feed the soldiers during the civil war. Many of the surviving elephants are

tuskless. Tuskless elephants in Gorongosa had a biological advantage. According to Joyce Poole, an elephant behavior expert and National Geographic Explorer who studies the park's pachyderms, decades ago about 4,000 elephants lived in Gorongosa. After the civil war, the population shrunk around the triple digits. Poole studied 200 adult females. According to Poole's research, 51 percent of those female elephants that survived the war (animals 25 years or older) are tuskless and 32 percent of the female elephants born since the war are tuskless.

Resources:

Selection for Tuskless Elephants

National Geographic- Under poaching pressure, elephants are evolving to lose their tusk

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.

Changing Tusks in Response to Poaching

Tusks are elongated teeth that protrude beyond the mouths of elephants. Both male and female African elephants have tusks. Tusks are used for digging holes, stripping bark from trees, fighting, and males use them to attract mates. If a male does not have tusks, he is at a great disadvantage for fighting for and finding a mate. In Gorongosa, tusklessness is a common trait among female elephants.

1. Identify the factors that caused the change in the population and provide reasoning for the predicted change.

Factor	**Evidence of factors in the population**	**Affect on population**

2. Predict what the population changes (if any) will occur in the next ten years.
3. Will competition within the population increase or decrease? Describe the evidence you have to support your position.

Universal Supports	Targeted Supports
● Engage in the phenomena with multiple forms of media (video, text, audio) ● Use a graphic organizer allow students record their ideas about: 1. Adaptation 2. Survival of the fittest 3. Evolutionary purpose ● Use graphic organizers, question guides, anticipation guides, or learning logs helps students comprehend and interpret texts. ● Provide students variety of ways to engage in discourse (pairs/whole group) and institute protocols for engaging in partner and whole group discourse	● Provide a partially completed graphic organizer allow students record their ideas about: 1. Adaptation 2. Survival of the fittest 3. Evolutionary purpose ● Group students together according to their misconceptions and provide necessary materials for reinforcement and individual teacher support ● Provide extended time to accomplish task and individual tutoring

Common Misconceptions

- Evolution is a theory about the origin of life.
- Evolutionary theory implies that life evolved (and continues to evolve) randomly, or by chance.
- Evolution results in progress; organisms are always getting better through evolution.
- Individual organisms can evolve during a single lifespan.
- Evolution is organisms adapting to their environment (an individual does not adapt-a species adapts)
- Survival of the fittest (it is not the strongest or healthiest that survives, it is the individual who is most"fit" for a specific environment)
- Evolutionary Purpose (there is no predetermined plan that progresses toward an ideal form)

Citation: https://evolution.berkeley.edu/evolibrary/misconceptions_faq.php#b1

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Use instructional resources (videos, images, articles) that are representative of all cultural groups in your classroom.

- Before conducting small group activity, make sure that all students understand the expectations, instructions, and their role in the performance of the task. The teacher may check for understanding by asking questions regarding the expectations and how to complete the task.
- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- Set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing. Involve students in setting these protocols and ground rules.
- Support ideas related to all organisms on Earth express traits inherited in their DNA and influenced by environmental factors.
- Reinforce that each organism has a unique combination of DNA sequences, but still share ancestry from a common line.
- Address differences in cultural and religious values or beliefs about the process of evolution. Allow students to maintain personal beliefs while encouraging learning about diverse perspectives. Reinforce that all ideas presented in science will be constructed from scientific evidence.
- Demonstrate evidence of multiple examples of ancestral lines through multiple time periods and focus on observable changes over time.
- All students can ask questions in the language of their choice, orally or written. Technology, such as Google Translate, can be used to support translation of various languages.
- Discuss causes of limited resources and provide local examples to demonstrate possible effects over time.

Students who demonstrate understanding can:

HS-LS4-3. **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [*Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency 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
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.	**LS4.B: Natural Selection** • Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. **LS4.C: Adaptation** • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. • Adaptation also means that the distribution of traits in a population can change when conditions change.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.LS2.A ; **HS.LS2.D** ; **HS.LS3.B**

Articulation of DCIs across grade-bands:
MS.LS2.A ; **LS3.B** ; **MS.LS4.B** ; **MS.LS4.C**

Common Core State Standards Connections:
ELA/Literacy -

RST-11.12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-LS4-3)*

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-LS4-3)*

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. *(HS-LS4-3)*

Mathematics -

MP.2 Reason abstractly and quantitatively. *(HS-LS4-3)*

Grade	*NGSS Discipline*
HS	**Life Science 4.3**
LS4-3	**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.* **Cliff Swallow RoadKill**

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

News: Evolution,Darwin Day

[redacted] swallows evolve around highways

In survey along Nebraska roads, number of birds killed by cars has plummeted over 30 years

By Meghan Rosen 12:48pm, March 18, 2013
Magazine issue: Vol. 183 #8, April 20, 2013, p. 17

Crossing the road has gotten easier for cliff swallows. Over generations, the mortal threat of speeding

An estimated 80 million birds are killed by colliding with vehicles on U. S. roads each year. In the 1970's along the I-80 highway in Keith County, Nebraska, drivers started noticing large numbers of dead swallows on the road. This led to a 45-year long study on swallow roadkill to figure out why this was happening.

Cliff Swallows traditionally built their nests on vertical cliff faces. However, with the expansion of roads, they have adopted many bridges, overpasses, and culverts as their colonial nesting sites. Their nests are grey or brown with openings at one end. Cliff Swallows zoom around in complicated aerial patterns to catch insects for food.

According to an article published in 2013 the researchers described how, “over the last 30 years, the number of cliff swallows killed along roads in southwestern Nebraska has plunged.

- A Peacock's Tail

Description:The tail of the male peacock is a great example of sexual selection. Female peafowl are attracted to male peacocks with the largest and most ornate train. The ability of male peacocks to create a large train is related to their overall fitness. Therefore females are more likely to have healthy chicks if they mate with a male with the largest train. Scientists were able to measure female choice by trimming the trains of normally healthy male peacocks which led to them not being selected as potential mates.

Web Resources:

[A Peacock's Tail — The Wonder of Science]

Classroom Assessment Items

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

The Cause

The table below shows some disadvantages and advantages of shorter and longer wings for bird flight.

Longer wings	Shorter wings
• Require less energy to use because there's less drag • Harder to change directions quickly, turning is slow • Take off speed is slow	• Require more energy to use • Easier to change direction quickly • Allow birds to take off quickly

Consider that the cliff swallows who live under highway bridges might need to get food from the road.

1. Do you think birds with longer wings or shorter wings are more likely to have an advantage that allows them to survive better in this new environment? (Circle one)

Longer wings Shorter wings

2. Explain your reasoning.

The Evidence

To explore a possible cause we will examine the evidence researchers have collected over the last 30 years. The following table includes the average wing length of birds that were collected from the population at large and those that were killed by cars.

Figure 1: Data collected on Swallow Wing Length

Google Spreadsheet of Data

Year	Average Wing Length (mm) **Population at large**	Average Wing Length (mm) **Roadkill**
1986	109.5	108.7
1987	108.5	108.7
1988	108.7	108.6
1989	108.3	108.2
1990	107.9	108.8
1992	107.8	109.1
1998	106.3	109.8
2000	107.2	109.8
2001	106.9	109.2
2002	107.4	110.0
2003	107.2	109.3
2004	107.0	109.1
2005	108.3	109.1
2006	107.9	110.0
2007	107.0	110.1
2010	106.4	111.0

2. Organize the data above into a scatter plot. Your graph should show the **pattern** of distribution of genetic traits over time. Include both a line of fit and a correlation coefficient for each dataset. Paste your plot on the next page.

Universal Supports

- Engage in the phenomena with multiple forms of media (video, text, audio)
- Encourage students to identify the long-term goals and break down into shorter objectives
- Encourage students to use graphic organizers to develop their claims
- Provide students variety of ways to engage in discourse (pairs/whole group) and institute protocols for engaging in partner and whole group discourse

Targeted Supports

- Monitor the students to provide individualized interventions and address misconceptions
- Provide sentence stems/starters to support developing written arguments, including cause and effect
- Provide extension opportunities for students or additional readings to go deeper in learning, for those students with high interests.
- Pull students into small groups to complete activities with a teacher or assistant leading the group to monitor for misconceptions or gaps in knowledge

Common Misconceptions

- Only organisms that look alike share a common ancestor.
- Except for differences between male and female, and young and old, all individuals in a population are the same.
- Populations adapt when all of the individual members gradually change their traits.
- Natural selection can happen only when there are sudden changes to the environment.
- Genetic variations arise in response to selective pressure.
- “Survival of the fittest” means that the strongest, fastest, fiercest individuals are the ones that get to reproduce.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Allow student choice in the populations examined.
- Provide multiple examples, from various kingdoms, demonstrating the distribution of traits through populations.
- Design multiple opportunities for students to express opinions, thoughts, and ideas analyzing data demonstrating change over time.
- Support students in the application of math to explain the observed variance in populations.
- Provide sentence starters and stems that the students can use to agree, disagree, clarify, confirm, extend, and build from what has been said during a group conversation.
- Allow students to represent ideas graphically, mathematically, and orally in the language of their choice. Technology, such as Google Translate can be used to support translation of various languages utilized.
- Encourage conversations on benefits of biodiversity in populations.
- Reinforce the importance of natural selection and adaptation on the expression of traits and mutations and how that can change based on the environment.

Students who demonstrate understanding can:

HS-LS4-4. **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Disciplinary Core Ideas

LS4.C: Adaptation

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

Crosscutting Concepts

Cause and Effect

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

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.

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

Articulation of DCIs across grade-bands:
MS.LS4.B ; **MS.LS4.C**

Common Core State Standards Connections:
ELA/Literacy -

RST-11.12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS4-4)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS4-4)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS4-4)
Mathematics -	
MP.2	Reason abstractly and quantitatively. *(HS-LS4-4)*

Grade	*NGSS Discipline*
HS	**Life Science 4.4**
LS4-4	**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.* Video: Why Do Humans Have Different Colored Skin? Description: Ultraviolet light can alter human skin color. The wide range of skin color is genetic and passed from our ancestors. A person with ancestors that lived in an area that received a lot of UV light (close to the equator) has darker skin. The darker skin served as protection against various things. A person with ancestors that lived in an area with little UV light (near the poles) has lighter skin. **Source:**

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.

Evolutionarily, each of us is African; the first people had darkly pigmented skin and were thus well-adapted to handle the high levels of UVR (ultraviolet radiation) in equatorial regions. UVR has both benefits and costs for the human body. On the plus side, when it strikes the skin it catalyzes Vitamin D, which is essential for bone and immune health; on the minus side, it can cause DNA damage and skin cancers.

Diagram 1: Skin Color Distribution

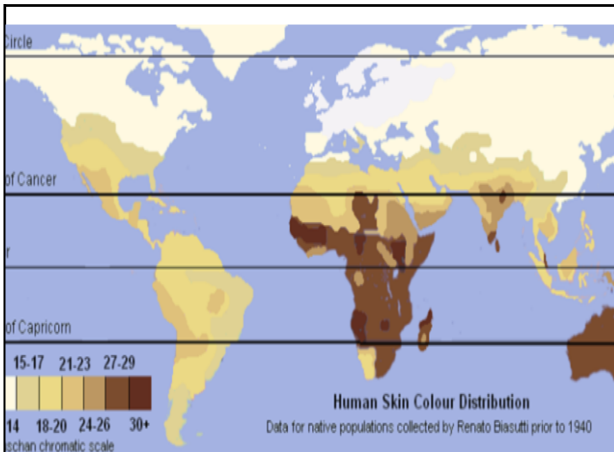
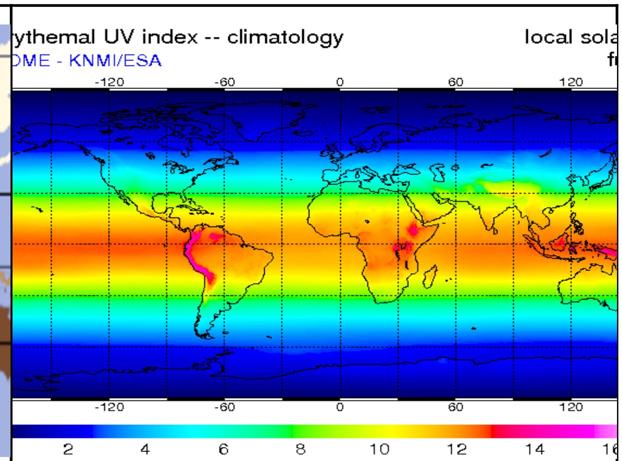


Diagram 2: UV Intensity



Jablonski, N. G., Chaplin, G., N.G.J., & G.C. (2003). Skin Deep. *Scientific American Special Edition*, *13*(2), 72-79.

1. Using the above maps, construct an explanation regarding the relationship between skin color and UV radiation exposure.
2. How is dark skin color in humans an adaptation to UV exposure at the equator?
3. Using the concept of natural selection, explain how the body's need for vitamin D caused the adaptation seen in skin color as humans migrated away from the equator.
4. Humans now have the ability to easily move around the globe, increasing the diversity of skin colors. Discuss some health implications with vitamin D deficiency.

Universal Supports	Targeted Supports
• Engage in the phenomena with multiple forms of media (video, text, audio)	• Monitor the students to provide individualized interventions and address misconceptions

- Encourage students to identify the long-term goals and break down into shorter objectives
- Encourage students to use graphic organizers to develop their claims
- Provide students variety of ways to engage in discourse (pairs/whole group) and institute protocols for engaging in partner and whole group discourse

- Provide sentence stems/starters to support developing written arguments, including cause and effect
- Provide extension opportunities for students or additional readings to go deeper in learning, for those students with high interests.
- Pull students into small groups to complete activities with a teacher or assistant leading the group to monitor for misconceptions or gaps in knowledge

Common Misconceptions

- Natural selection involves organisms trying to adapt.
- Natural selection gives organisms what they need.
- Humans can't negatively impact ecosystems, because species will just evolve what they need to survive.
- Natural selection acts for the good of the species.
- The fittest organisms in a population are those that are strongest, healthiest, fastest, and/or largest.
- Natural selection is about survival of the very fittest individuals in a population.
- Natural selection produces organisms perfectly suited to their environments.
- All traits of organisms are adaptations.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Reinforce collaboration through diverse cooperative grouping.
- Ensure that a variety of physical traits, such as the full spectrum of skin color, is demonstrated in examples provided.
- Show students discrepant events in observable characteristics in various populations.
- Allow students an opportunity to discuss the difference and connections between natural selection, adaption, and evolution.
- Ask students to consider all of their known familial ethnicities in consideration of their observable traits.
- Discuss the difference between observable and non-observable traits.
- Make considerations for students who are color blind and are not able to determine various colors during identification of observable traits.
- All students can present arguments in the language of their choice, orally or written. Technology, such as Google Translate can be used to support translation of various languages utilized.
- Encourage students to present, in any modality, examples from their life which demonstrates how traits passed from parents to offspring (family connections, pets, etc…)
- Encourage conversations on benefits of biodiversity in populations.
- Reinforce the importance of environmental factors on the expression of traits and mutations.

Students who demonstrate understanding can:

HS-LS4-5. **Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science. • Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. • Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-band:
HS.LS2.A ; ***HS.LS2.D*** ; ***HS.LS3.B*** ; ***HS.ESS2.E*** ; ***HS.ESS3.A***

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

Common Core State Standards Connections:
ELA/Literacy -
RST-11.12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5)
WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS4-5)
Mathematics -
MP.2 Reason abstractly and quantitatively. *(HS-LS4-5)*

Grade	*NGSS Discipline*
HS	**Life Science 4.5**
LS4-5	**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.* **The Great Oxygenation Event** **Description:**The Great Oxygenation Event occurred when cyanobacteria living in the oceans started producing oxygen through photosynthesis. As oxygen built up in the atmosphere anaerobic bacteria were killed leading to the Earth's first mass extinction. The change in diversity and the arrival of appreciable atmospheric oxygen (as evidenced by the red bands in the rocks) can be analyzed to see what happens when a resource that was scarce becomes very abundant. **Web Resource:** The Great Oxygenation Event — The Wonder of Science

- *The Asteroid That Killed The Dinosaurs*

Description: It is estimated that 75% of plant and animal (including dinosaur) species went extinct after the Earth was hit with a massive asteroid 66 million years ago. Evidence includes a thin layer of rock containing iridium (rarely found on Earth but common in asteroids) around the planet. Scientists have also discovered a large impact crater. The cause of the extinction is fairly clear but the details of the effects leave much to be explored.

Web Resource: The Asteroid That Killed The Dinosaurs — The Wonder of Science

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.

Scenario

The primary food source of monarch Butterfly larvae is the milkweed plant. The invasive swallow wort plant has been introduced to NY from Europe. Monarchs are often fooled into laying their eggs on these plants, but their larvae do not survive upon eating the plant.

Data

Monarch Population (1970-1990) before swallow introduction

Year	# of Monarch Butterflies
1970	910
1975	850
1980	900
1985	790
1990	915

Monarch Population (1990-2010) after swallow introduction

Year	# of Monarch Butterflies
1990	910
1995	850
2000	900
2005	790
2010	915

Bob thinks that in 2020 the swallow wort population will decline and the Monarch population will increase.

1. What is Bob's claim?
2. Do you agree or disagree with Bob's claim? What is your reasoning?
3. If you agree with Bob's claim, what evidence did Bob used to make his claim?
4. If you disagree, what additional evidence is needed?

Web resource: HS-LS4-5: Environmental Change - Speciation and Extinction

Universal Supports	Targeted Supports
• Engage in the phenomena with multiple forms of media (video, text, audio) • Encourage students to identify the long-term goals and break down into shorter objectives • Encourage students to use graphic organizers to develop their claims • Provide students variety of ways to engage in discourse (pairs/whole group) and institute protocols for engaging in partner and whole group discourse	• Monitor the students to provide individualized interventions and address misconceptions • Provide sentence stems/starters to support developing written arguments, including cause and effect • Provide extension opportunities for students or additional readings to go deeper in learning, for those students with high interests. • Pull students into small groups to complete activities with a teacher or assistant leading the group to monitor for misconceptions or gaps in knowledge

Common Misconceptions

- Evolution is not a result of genetic variation of individuals in a species, competition for resources, and proliferation of organisms better able to survive and reproduce.
- Adaptation does not mean that the distribution of traits in a population, as well as species expansion, emergence or extinction, can change when conditions change.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Before conducting small group activity, make sure that all students understand the expectations, instructions, and their role in the performance of the task. The teacher may check for understanding by asking questions regarding the expectations and how to complete the task.
- Be mindful of how students are grouped. If the task does not demand homogeneous grouping by race, gender, or ability, make sure that each group is diverse and represents a different cultural background.
- Model cooperative learning strategies to encourage positive community interactions within the classroom.
- Support diverse ideas on evolution and natural selection, while maintaining a focus on scientific evidence.
- Use videos or articles that are representative of all cultural groups in your classroom.
- Set protocols and ground rules for conducting small group activity, conversation, affirming, and respectful ways of disagreeing. Involve students in setting these protocols and ground rules.
- Provide sentence starters and stems that the students can use to agree, disagree, clarify, confirm, extend, and build from what has been said during a group conversation.
- When conveying information during whole group discussion and conversation, limit the presentation to 5 - 10 minutes and provide visual examples for the concepts or information.

	• If students are experts or interested in certain aspects of the activity or concepts being presented in the activity, assign these students to become the resource person for their area of expertise or interest. Refer students to them if they have questions about the task that relates to the resource person's expertise or interest.

Students who demonstrate understanding can:

HS-LS4-6. **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** [Clarification Statement: Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create or revise a simulation of a phenomenon, designed device, process, or system.	**LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. **LS4.D: Biodiversity and Humans** • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. *(Note: This Disciplinary Core Idea is also addressed by HS-LS2-7.)* **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(secondary)* • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. *(secondary)*	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to other DCIs in this grade-band:
HS.ESS2.D** ; **HS.ESS2.E** ; **HS.ESS3.A** ; **HS.ESS3.C** ; **HS.ESS3.D

Articulation of DCIs across grade-bands:
MS.LS2.C** ; **HS.ESS3.C

Common Core State Standards Connections:
ELA/Literacy -

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. *(HS-LS4-6)*

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-LS4-6)*

Grade	NGSS Discipline
HS	**Life Science 4.6**
LS4-6	**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.

SimRiver Simulation - Diatom Project (Simulation)

Description: The SimRiver Simulation, developed by Dr. Shigeki Mayama's lab at Tokyo Gakugei University, models human impact on water quality of a river. Settings within the simulation help students to make sense of this phenomenon by allowing them to mimic changes in land use along the river, population size, the presence/absence of sewage treatment, and season of the year. Using diatoms as indicator species of water quality, students identify diatoms from water samples, determine the saprobic index (a measure of water quality), and compare the impact of different human land and water uses along the river. As students become familiar with the simulation, they can use it to plan investigations and explore possible solutions to mitigate adverse impacts of human actions on water quality, and thus biodiversity. Instructional supports include background information, instructions for using the simulation, a printable student worksheet, and three levels of student support through different challenge settings.

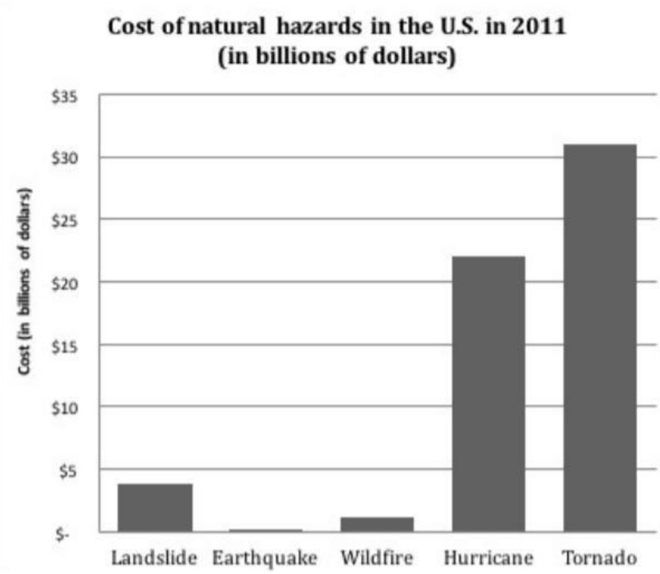
Web Source: *SimRiver Simulation - Diatom Project*

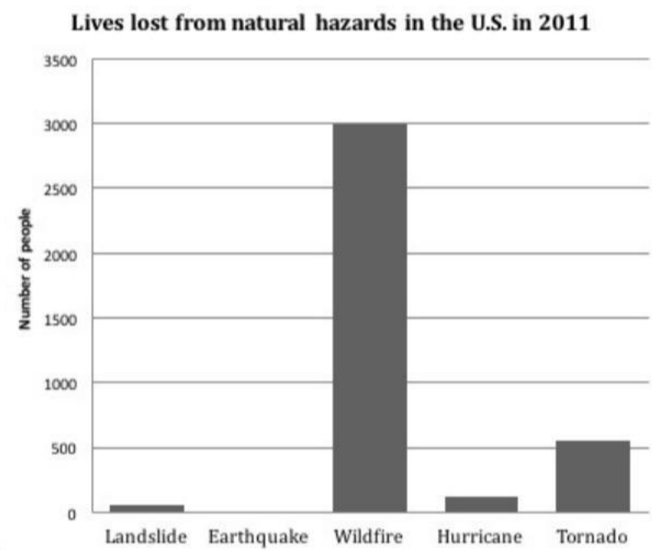
Classroom Assessment Items

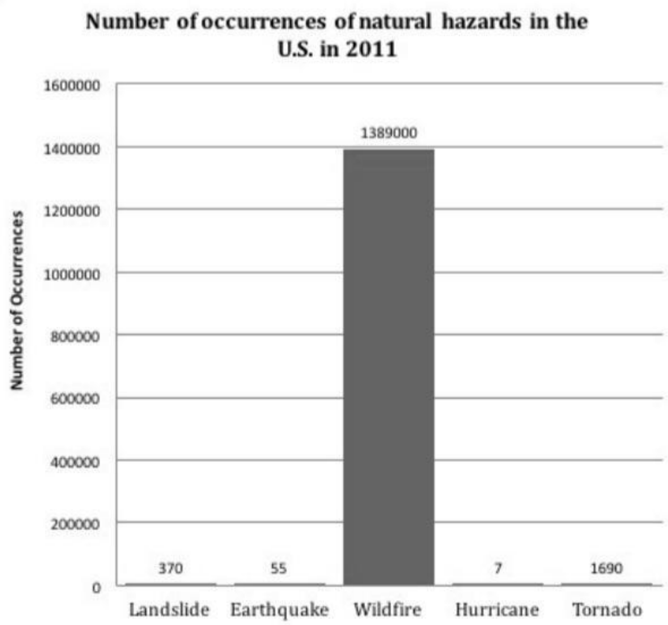
When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

Your city needs to create an emergency plan for natural hazards. An emergency plan describes what a city will do to prepare for the impacts of natural hazards. You have been asked to show city leaders how data can be used to help.

Below are three graphs showing data from natural hazards that occurred in the United States in 2011.


Cost of natural hazards in the U.S. in 2011
(in billions of dollars)
Cost (in billions of dollars)
$35
$30
$25
$20
$15
$10
$5
$-
Landslide
Earthquake
Wildfire
Hurricane
Tornado


Lives lost from natural hazards in the U.S. in 2011
Number of people
3500
3000
2500
2000
1500
1000
500
0
Landslide
Earthquake
Wildfire
Hurricane
Tornado



1. City leaders need help understanding how to interpret the data. To help them:

- Choose one of the hazards from the first column below and circle it.
- Use that hazard to complete the table

Circle the hazard you chose.	Describe what the graphs show about this hazard in 2011.	List at least 2 things that you know can cause this hazard.	List ways that you know this hazard impacts (affects) humans and the environment.
Landslide Earthquake Wildfire Hurricane			

2. Describe to the city leaders some ways the hazard you chose could affect their city. Use data from the graphs and other information from the table above to support your description.

- For example, tornadoes are rare and only happen in a few places in the US. When they do happen they destroy everything in their path, including the entire town. This pattern could explain why the cost of tornadoes was the highest of any hazard even though there were fewer than most other hazards in 2011.

3. You have found that you need to know a lot more about the natural hazards data than what is shown in the three graphs on Page 1.

Describe additional information about the graphs that city leaders would need before they could use the data to make decisions about solutions. Explain why leaders would need this additional information.

Web Resource: HS-LS4-6: Human Impact on Biodiversity Solution

Universal Supports	Targeted Supports

• Engage in the phenomena with multiple forms of media (video, text, audio)
  ○ Demonstrate examples of human impact on biodiversity through videos, journal articles, podcasts and kinesthetic manipulatives. Examples may include:
    ■ Farming and its impact that led to the Dust Bowl
    ■ Trawling for fish and its impact on the seafloor
    ■ Oil spills in the Gulf of Mexico
    ■ Dog breeding for American Kennel Club Breeds, which leads to lower diversity of breeds
• Encourage students to identify the long-term goals and break down into shorter objectives
• Encourage students to use graphic organizers to develop their claims
• Provide students variety of ways to engage in discourse (pairs/whole group) and institute protocols for engaging in partner and whole group discourse
	• Monitor the students to provide individualized interventions and address misconceptions
	• Provide sentence stems/starters to support developing written arguments, including cause and effect
	• Provide extension opportunities for students or additional readings to go deeper in learning, for those students with high interests.
	• Pull students into small groups to complete activities with a teacher or assistant leading the group to monitor for misconceptions or gaps in knowledge

Common Misconceptions

- Extinction of plants and animals is normal and natural, and just part of life.
- One species going extinct is not a big deal, and won't affect people.
- Everytime the environment is mentioned in the news it's bad news.
- If a species goes extinct evolution will replace it.
- We already know all of the species on Earth.
- Nothing I do has any effect on biodiversity, positive or negative.

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

	• Provide diverse grouping opportunities to support student learning from multiple perspectives. • Acknowledge the difference in perspectives on the role of humans and their impact on our environment. • Ask students to share examples of group behavior they have observed in the language of their choice. Technology, such as Google Translate can be used to support translation of various languages utilized. • Support students in the application of math to explain the observed variance in populations. • Allow student choice to investigate the topic of group behavior of their interest. • Provide examples of various formats and strategies to engage in argument from evidence on their topic. • Mini-lesson on how to write a claim, or the CER format, may be needed by some students. • Allow students to represent ideas in the language and format of their choice. Technology, such as Google Translate can be used to support translation of various languages utilized.

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.