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New Mexico STEM Ready! Science Standards Implementation Guide

Overview

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

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

The standards

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

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

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

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

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

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

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

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

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

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

- Read the connections box
    - When reading the connections to other DCI at this grade level that are relevant to the standard, consider the following question:
        - How can instruction be designed so that students note the connections between the core ideas?
    - When reading the articulation of DCI across grade levels that are relevant to the standard, consider the following questions:
        - Examine the standard at earlier grade levels, do they provide an adequate prior knowledge for the core ideas in the standard being reviewed?
        - Examine the standard at later grade levels, does the standard at this level provide adequate prior knowledge for the core ideas in the later standards?
    - When reading the *CCSS* in mathematics and English language arts (ELA), consider the following questions:
        - Should students have achieved these mathematics and ELA standards to engage in the learning of 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

Heredity: Inheritance and Variation of Traits
HS-LS3-1
HS-LS3-2
HS-LS3-3

Students who demonstrate understanding can:

HS-LS3-1. **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.** [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

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
Asking Questions and Defining Problems Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from examining models or a theory to clarify relationships.	**LS1.A: Structure and Function** • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. *(secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)* **LS3.A: Inheritance of Traits** • Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.	**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: N/A

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

Common Core State Standards Connections:
ELA/Literacy -
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-LS3-1)*
RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-LS3-1)*

Grade	*NGSS Discipline*
HS	**Life Science 3.1**
LS3-1	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following are example phenomena you can use if you don't have local instructional materials available.*

Phenomena #1 - DNA Test Kits

- **Description:** To launch this standard, students will ask questions based on the investigation of DNA test kits, in relation to the following essential question: What is DNA and what information does a DNA test provide? To begin, ask students to consider commercials advertisements that they have seen on at-home DNA test kits. If your students are not familiar with them, you can play a sample commercial. Based on the initial ideas of at-home DNA test kits, ask students to consider if they would be willing to take one, what information it would provide, and if there are any concerns related to using this technology (**cause and effect - CCC**)? Following that conversation, play "The at-home DNA test craze is putting us all at risk" video (linked below) for students and have each student write three individual questions (**asking questions- SEP)** that they have about at-home DNA test kits, DNA, or technology concerns. Each question should be placed on it's own post-it note. Once all students have their questions recorded, follow the Driving Question Board process (linked below) to have all students share their questions and categorize them into a visual representation. The questions generated by students should then be used to drive following instruction about DNA and inheritance of traits. The "What DNA ancestry test can and can't tell you" video can be used as a connection piece later in the instructional process.
- **Resources:**
    - "The at-home DNA test craze is putting us all at risk" video
    - **"**What DNA ancestry test can and can't tell you" video
    - What is a Driving Question Board? - OpenSciEd Resource

Phenomena #2 - Family Trees

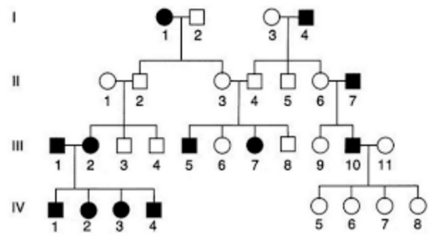
- **Description:** To explore inheritance from parents to offspring, students can consider their own family to determine how traits are inherited based on the essential question: Why do some families look very similar and others do not? To begin, you can show examples of families who demonstrate similar physical characteristics and others with very different physical characteristics. Students can then bring in pictures of their family members and compare them with other students considering the essential question. Based on the initial questions, ask students to consider what causes these differences and why they vary by family (**cause and effect - CCC**). Following that process, have each student write three individual questions (**asking questions- SEP)** that they have about how traits are passed from parents to offspring. Each question should be placed on it's own post-it note. Once all students have their questions recorded, follow the Driving Question Board process (linked below) to have all students share their questions and categorize them into a visual representation. The questions generated by students should then be used to drive following instruction about DNA and inheritance of traits. Remember to be thoughtful when implementing this phenomenon as students may have diverse relationships with biological family members.
- **Resources:**
    - What is a Driving Question Board? - OpenSciEd Resource

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.

Rabbit Genetics Task

- Your friend has a white rabbit farm. By the 4th generation, there are no longer any long haired males. (Long-hair is dominant to short-hair) Your friend asks you to help explain how this could happen. Using the model(s), write two research questions: one should support the claim that DNA is inherited from parents to offspring and the other question should be related to the cause and correlation between DNA and the proteins it codes for and the resulting trait observed in an organism

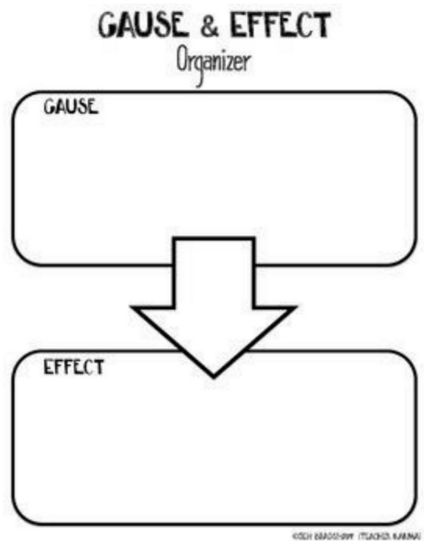


https://www.mun.ca/biology/scarrl

colorgentics.info

colorgenetics.info

- After having so many rabbits your friend had to place a number of them outside during the winter. The rabbits had never been kept in such cold temperatures. After about a month, your friend noticed dark fur growing in the extremities. Write a research question using your knowledge of gene regulation to explore what happened?
- Fill in the following graphic organizer to support the new research question.



- Design an experiment to test your new question.
- Referring to question 4 what data would you collect to support your research question.

Citation:

- The Short Performance Assessment (SPA) and the Assessment Rubric adapted from the Stanford NGSS Assessment Project http://snapgse.stanford.edu/
- This work is licensed by the author(s) under a Creative Commons Attribution-NonCommercial 4.0 International License. Hosted by The Wonder of Science. HS-LS3-1 Assessment - Rabbit Genetics (NY)

Universal Supports	Targeted Supports
• Following the phenomenon presented for this standard, ask students to explore an additional real-world example of inheritance of traits through DNA that demonstrate discrepant events, such as baby animals that do not have similar appearance to their parents, that can connect to the questions asked during the phenomenon. • Ask students to develop a second round of **questions** that specifically on the processes that allows for inheritance of traits from parents to offspring and the variations observed in physical characteristics. • Utilize the student generated questions to identify current levels of understanding of DNA and misconceptions. Students can participate in a DNA extraction lab (strawberries work well) to visualize the DNA contained within living organisms. Based on the DNA extraction lab, students can create a model demonstrating	• Students who require targeted intervention may benefit from modeling the structure of DNA and base pairing rules, in addition to macromolecules and protein synthesis. • In small groups, students should review DNA structure, Punnett squares, and pedigrees with teacher assistance

the structure and function of DNA found in the strawberry, an explanation of where the strawberries get DNA from, and how the DNA found in the strawberry determines the observable traits of that organism. Then, have students apply the structure of DNA, where traits are carried on DNA, the organization of DNA into chromosomes, and how traits are passed from parent to offspring through the process of meiosis. The focus should be on students making connections between the cause and effect of the structure of DNA, and how it codes for protein, and the inheritance and traits through meiosis and reproduction.

- Punnett squares and pedigrees can be used as visual supports for understanding the process.
- Student generated questions should be addressed by the end of the instructional sequence to purposefully address misconceptions and clarify understanding.

As this standard contains multiple facets and requires background information on DNA structure and function, careful consideration should be given to which standards this one is bundled with and the overall instructional sequence of inheritance of traits.

Common Misconceptions

- **Disciplinary Core Ideas (DCI's)**
  - Students may have misconceptions or gaps in learning on the **Structure and Function of DNA** and **Inheritance of Traits** related to the following concepts:
    - All living things are not made up of cells.
    - Cells do not support the growth, survival, behavior, and reproduction of organisms.
    - Multicellular organisms do not have specialized systems of cells that perform feedback mechanisms to maintain homeostasis or the misidentifying the difference between a positive and negative feedback loop.
    - Sexual and asexual reproduction uses the same process to pass traits from parent to offspring.
    - Something other than DNA carries instructions for forming all species characteristics.
    - All expressed traits are dominant.
    - In sexual reproduction, not thinking that each parent contributes half of the genes acquired by the offspring resulting in variation between parent and offspring.
    - Different types of cells have different genetic information.
      - Each cell in an organism has the same genetic information, but gene expression by cells can differ.
    - All mutations in DNA are harmful.
      - Mutations in DNA can alter genetic information which can be beneficial, negative, or have no effect on an organism.

- **Science & Engineering Practices (SEP's)**
  - Students may not know what **questions to ask** about inheritance of traits to:
    - Determine the relationship between DNA, chromosomes, proteins, and expressed traits.
    - Explain discrepant events in physical traits demonstrated in organisms (expression of recessive traits)
- **Crosscutting Concepts (CCC's)**
  - Students may not be able to connect the **cause and effec**t relationship between how:
    - DNA hold genetic information and is organized into chromosomes
    - Genes regulate proteins, which causes gene expression
    - Mutations in DNA do not always cause a change in gene expression

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.
- Ensure that a variety of physical traits, such as the full spectrum of skin color, is demonstrated in examples provided.
- Use examples from each kingdom to represent the diversity of life on Earth.
- Allow students an opportunity to discuss the difference between biological family and members of their family they are not biologically related to through DNA.
- Make considerations for students who are color blind and are not able to determine various colors during identification of observable traits.
- 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.
- Encourage students to present, in any modality, examples from their life which demonstrates how traits passed from parents to offspring (family connections, pets, etc…)

Students who demonstrate understanding can:

HS-LS3-2. **Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

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

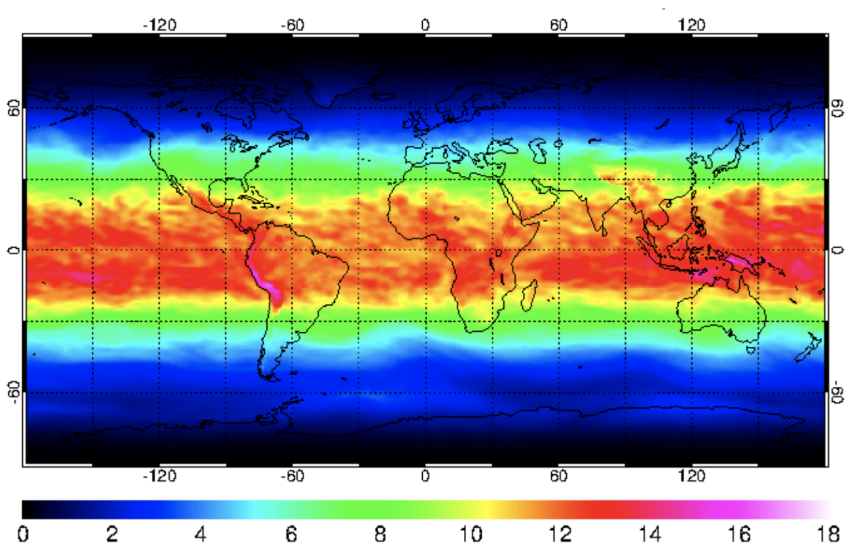
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.	**LS3.B: Variation of Traits** • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	**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: N/A

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

Common Core State Standards Connections:
ELA/Literacy -
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-LS3-2)*
WHST.9-12.1 Write arguments focused on *discipline-specific content.* (HS-LS3-2)
Mathematics -
MP.2 Reason abstractly and quantitatively. (HS-LS3-2)

Grade	*NGSS Discipline*
HS	**Life Science 3.2**
LS3-2	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following are example phenomena you can use if you don't have local instructional materials available.* **Phenomena #1 - Skin Color** ● **Description:** A well suited phenomenon to explore related to this standard addresses skin color. The standard specifies three factors for genetic variations, all of which can be introduced through the correlation between amount of UV radiation geographically and skin color. To begin, have students watch the beginning section of the "Biology of Skin Color" video from HHMI Biointeractive. As students watch the video, they should record evidence presented regarding variation in skin color (**engaging in argument from evidence- SEP).** Next, as students analyze a UV radiation map (example below) and consider the relationship between environmental conditions and skin color (**cause and effect - CCC**). This phenomenon can then be related to inheritance of traits from parents to offspring and mutations caused by UV radiation due to environmental factors.



- **Resources:**
  - The Biology of Skin Color - HHMI Biointeractive resource
  - Human Skin Color - HHMI Biointeractive resource

Phenomena #2 - Black & White Twins

- **Description:** Another approach is to investigate the variations of traits within family members. Ask students to consider the picture below and write observations of the physical characteristics of the two individuals shown (**engaging in argument from evidence- SEP).** Then, have students read the "Black and White Twins" article and document the reasons related to inheritance of traits that would explain the variation observed between the twins (**cause and effect - CCC**). This phenomenon focuses on inheritance of traits based on meiosis. The other two factors of genetic variation would need to be addressed through the following instruction.

- **Resources:**
  - Black and white twins article

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.

Twins with Different Skin Colors Task

- Meet the 11-year-old twins with two different skin tones. There's no trouble telling these 11-year-old twins apart. Marcia and Millie Biggs looked almost identical when they were born but their difference in skin tone became more apparent as they aged. As brown-eyed Millie started to become darker skinned, blue-eyed Marcia took on a lighter complexion and grew blonde, curly hair. The twins' mom is white, while their dad is Jamaican.

The image shows the UK family from the video. The image includes (from left to right) Mom, Millie, Marcia, and Dad. Millie and Marcia are twins; they were born from the same parents at the same time.

Image source:
https://www.serumpi.com/71970/hiburan/aneh-tapi-nyata-10-anak-kembar-ini-punya-keunikan-beda-warna-kulit

Table 1 : the various shades of human skin colour

Phenotypes	Genotypes	Units of pigment
Extremely dark	AABBCC	6
Very dark	AaBBCC	5
Dark	AaBbCC	4
Intermediate	AaBbCc	3
Light	aaBbCc	2
Very light	aabbCc	1
Extremely light	aabbcc	0

Table 1 shows the genotypes for the different observable phenotypes of skin color.
Source: http://ibbiology.wikifoundry.com/page/Explain+that+polygenic+inheritance+can+contribute+to+continuous+variation

- Based on the evidence from the video and images, make and defend a claim that explains how these twins have different skin colors, even though they have the same parents.

Stimulus

Figure 1

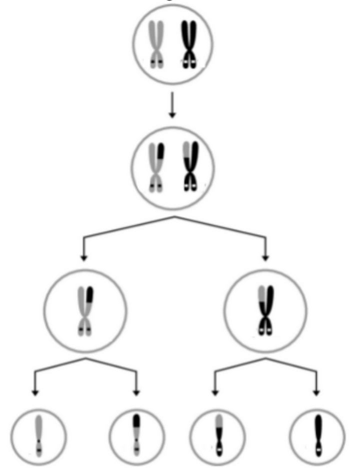
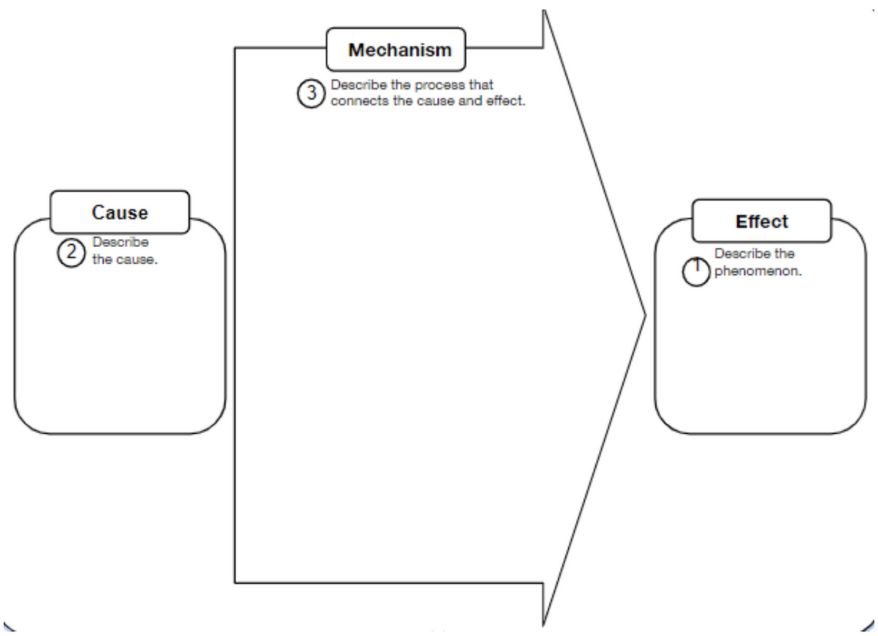


Figure 1 shows a biological process that occurs during sexual reproduction.
Source: https://www.researchgate.net/figure/Segregation-of-homologous-chromosome-during-meiosis-explains-Mendels-law-of-segregation_fig1_310995415

- Using Figure 1, provide a biological explanation that includes reasoning for the genetic variation between the twins.
- Marcia and Millie enjoy a weekend at the beach with their parents. Everyone had a fun time, but when they got home, Marcia's skin was red and very uncomfortable for a few days. Fill in the chart below to make a claim about the cause of Marcia's condition.



- As the twins got older, their mother was diagnosed with breast cancer. Mom took the test to find out if she carried the breast cancer gene (BRCA1). The test came back negative. In addition to lacking the breast cancer gene, Marcia and Millie's mother had not been exposed to any carcinogens. Select the biological event below that is the most likely cause for their mother's breast cancer. Then, in the space provided, use scientific evidence to support your claim.
    - Mutations resulting from environmental factors
    - Mutations resulting from errors in DNA replication

- New genetic combinations during cell division
- Some human health conditions like cancer are caused by genetic and environmental factors.
    - Should Marcia and Millie be concerned about their risk for developing breast cancer as they get older? Support your claim with an explanation that includes your understanding of genetics.
    - Identify two actions that Marcia and Millie can take to limit their risk of developing cancer.
    - Describe how these actions would help to prevent cancer later in life.

Citation:

The Short Performance Assessment (SPA) and the Assessment Rubric adapted from the Stanford NGSS Assessment Project [Stanford NGSS Assessment Project |]

[HS-LS3-2 Assessment - The Twins with Different Skin Colors (NY)]

Universal Supports	Targeted Supports
• Preceding the phenomenon, based on skin color, present students with a list of organisms (at least one from each kingdom) and ask students to make a prediction about how much DNA humans and each organism then share with the class. Once revealing the answers, ask students to consider why most organisms have common ancestry and demonstrated through shared DNA and yet look so different. Students can then share their diverse ideas and engage in **arguments from evidence** to support their claims. • Then provide multiple opportunities, through multiple modalities for students to engage in learning about meiosis, DNA crossover, replication errors, and environmental factor’s impact on genetic variation. Examples should be provided from several kingdoms to support connections to student’s background knowledge and focus on **cause and effect.**	• Small group instruction should be provided to students who need additional support on concepts related to DNA, the process of meiosis. • Clear distinctions and connections between the three ways inheritable genetic variations are established should be made. Video resources that visualize components of the processes involved can support visual and auditory learners. • Some students may also need strategic guidance on the claim, evidence, reasoning model and how to apply this strategy to explain their thinking.

Common Misconceptions

- **Disciplinary Core Ideas (DCI’s)**
    - Students may have misconceptions or gaps in learning on the **Variation of Traits** related to the following concepts:
        - Mitosis and meiosis is the same process..
        - The difference between DNA, alleles, and chromosomes.
        - Meiosis does not create genetic variation.
        - Environmental conditions do not affect the traits that organisms develop.

        - Some mutations in DNA are not passed from parent to offspring.
- **Science & Engineering Practices (SEP's)**
    - Students may not know how to **engage in argument** about variations of traits to support:
        - The variation and distribution of traits in a population and their dependence on genetic and environmental factors.
        - Increased genetic variation is created through crossover of chromosome sections.
- **Crosscutting Concepts (CCC's)**
    - Students may not be able to connect the **cause and effect** relationship between how:
        - Environmental factors can cause mutations in DNA or affect gene expression
        - Different organism vary in how the look and their function because they have inherited and expressed different genetic information, although many organisms share to significant amount of the same DNA

Culturally and Linguistically Responsive Instruction

Guiding Questions and Connections

- Reinforce collaboration through diverse cooperative grouping.
- Restate classroom norms and model respectful discussions regarding variation of observable traits.
- 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 between biological family and members of their family they are not biologically related to through DNA.
- 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-LS3-3. **Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [*Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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.	**LS3.B: Variation of Traits** • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	**Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). - ***Connections to Nature of Science*** **Science is a Human Endeavor** • Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3) • Science and engineering are influenced by society and society is influenced by science and engineering.

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

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

Common Core State Standards Connections:
Mathematics -
MP.2 Reason abstractly and quantitatively. (HS-LS3-3)

Grade	*NGSS Discipline*
HS	**Life Science 3.3**
LS3-3	**Sample Phenomena** *When available, you should use your locally selected or created high quality instructional materials. However, the following are example phenomena you can use if you don't have local instructional materials available.* **Phenomena #1 - Sickle Cell Anemia & Malaria** ● **Description:** This phenomenon supports the concept of natural selection in humans and distribution of this trait throughout the world. Have students watch the "Malaria and Sickle Cell Anemia" video and draw a connection between sickle cell disease and malaria (**analyzing and interpreting data- SEP)** and then explain why the distribution of this trait is varied (**scale, proportion, and quantity - CCC**). ○ **Resources:** ■ Natural Selection in Humans: Malaria and Sickle Cell Anemia - HHMI Biointeractive video **Phenomena #2 - Rock Pocket Mouse** ● **Description:** To introduce the process of applying statistics to explain variation in populations, the Rock Pocket Mouse is a New Mexico based phenomenon that asks students to explore the variation in colors of mice based on their location.Mice living on light-colored sand tend to have light-colored coats, while mice

living on patches of dark-colored rock have mostly dark-colored coats. Have students watch the beginning of "The Making of the Fittest:Natural Selection and Adaptation" video and make predictions on how the differences in the environmental conditions led to the variations in Rock Pocket Mouse color variation (**analyzing and interpreting data- SEP)** and the predicted proportion of each color variation of mice in each location (**scale, proportion, and quantity - CCC**).

- **Resources:**
    - The Making of Fittest: Natural Selection and Adaptation - HHMI Biointeractive video

Classroom Assessment Items

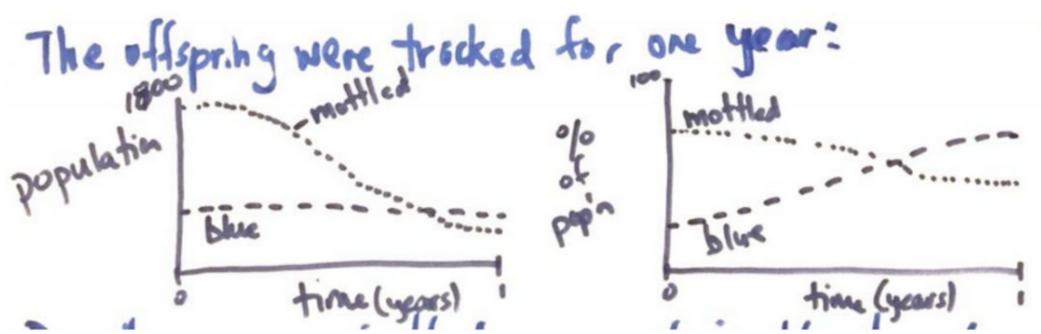
When available, you should use your locally selected or created high quality instructional materials. However, the following are example assessment items you can use if you don't have local instructional materials available.

Polynesian Butterflies Task

- A new species of Polynesian Butterflies was discovered. The population consists of two discrete phenotypes (solid blue and mottled orange/black ventral surfaces). A cross of two individuals produced the following data:

	Blue	Mottled
Female	222	778
Male	302	698

- Construct a model that would illustrate the inheritance pattern for the above cross.
- State which allele is dominant? Use evidence to support the answer.
- Determine if the gene locus for this trait resides on an autosome or sex chromosome. Use evidence to support your answer.
- Determine the genotypes of both parents. Use statistical analysis to support your claim.
- The offspring were tracked for one year. Describe a scenario that can explain the trends in the below graphs.



Citation:

The Short Performance Assessment (SPA) and the Assessment Rubric adapted from the Stanford NGSS Assessment Project Stanford NGSS Assessment Project |

Universal Supports	Targeted Supports
• Provide students opportunities to organize the given data by the frequency, distribution, and variation of expressed traits in various populations. • Students should be able to use appropriate statistical analyses of data, including probability measures to determine the **relationship** between a trait's occurrence within a population and environmental factors. • Punnett squares and pedigrees, along with environmental factors for the population can support this process. • Students **analyze and interpret data to explain the distribution of expressed traits**, including: recognition and use of patterns in the statistical analysis to predict changes in trait distribution within a population if environmental variables change; and description of the expression of a chosen trait and its variations as **causative or correlational** to some environmental factor based on reliable evidence. • For each mutation example provided, students should consider if the mutation would be heritable or not and why.	• Students may need additional support in reading and analyzing data and graphs, creating graphs. • Students do not have background knowledge on meiosis, punnett squares, and pedigrees may require small group mini-lessons on those topics

Common Misconceptions

- Disciplinary Core Ideas (DCI's)
  - Students may have misconceptions or gaps in learning on the **Variation of Traits** related to the following concepts:
    - All populations of organisms have the same traits.
      - Variation and distribution of traits depend on genetic and environmental factors.
    - Genetic variation only results from mutations.
      - Mutations can be caused by environmental factors and errors in DNA replication, or from chromosome crossover during meiosis.
- Science & Engineering Practices (SEP's)
  - Students may not know how to **analyzing and interpreting data** about variations of traits to:
    - Applying statistics and probability to support why populations and individuals have variations in traits.
- Crosscutting Concepts (CCC's)
  - Students may not be able to connect the **scale, proportion, and quality** between:

- The variation and distribution of traits in a population depend on genetic and environmental factors.

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.
- 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 environmental factors on the expression of traits and mutations and how that can change based on region.

Section 3: Resources

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

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

Engaging in the Practices of Science

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Crosscutting concepts

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

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

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

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

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

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

Planning Guidance for Culturally and Linguistically Responsive Instruction

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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