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NM STEM Ready! Science Standards Implementation Guide

Overview

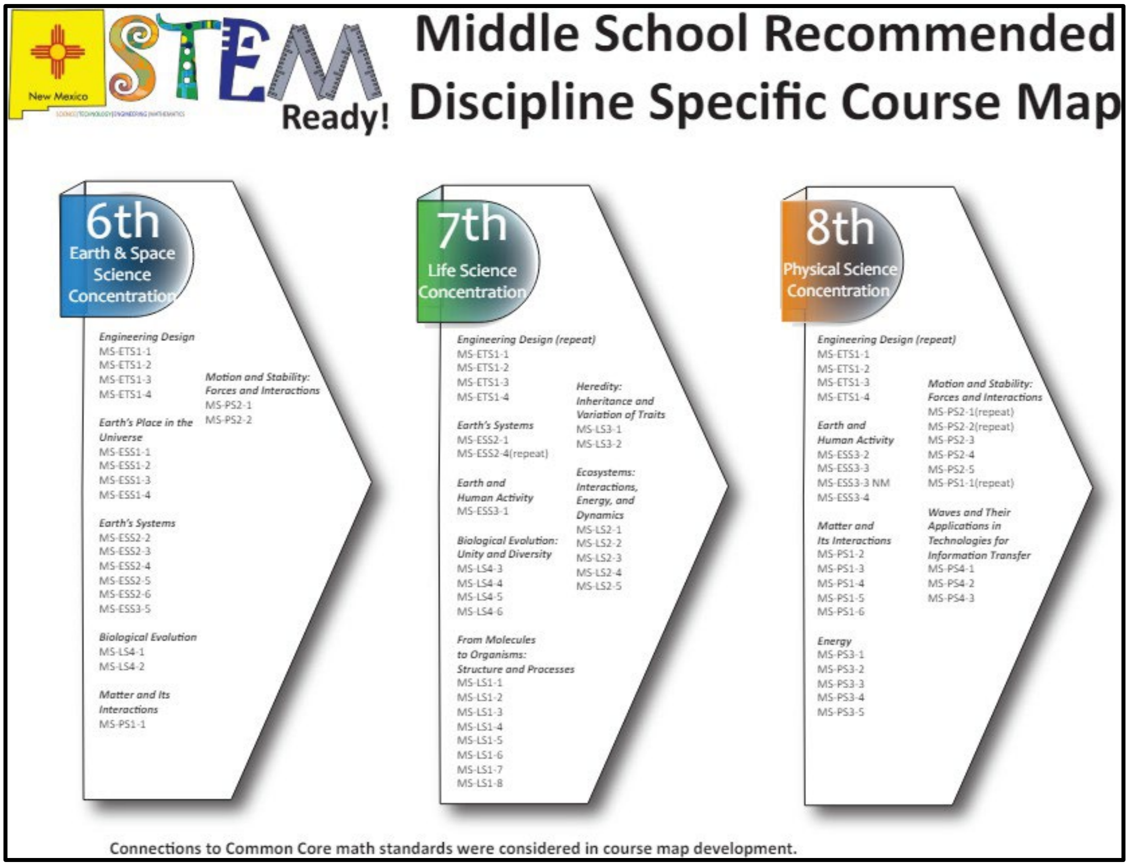
A Framework for K–12 Science Education marks a leap forward in how we think about science education and captures the advancements made in understanding how students best learn science that have been made over the last 30 years. The New Mexico Public Education Department (PED) and New Mexico public school teachers worked together over the course of spring 2024 to construct an updated Instructional Scope 2.0 document for the New Mexico STEM Ready! Science Standards.

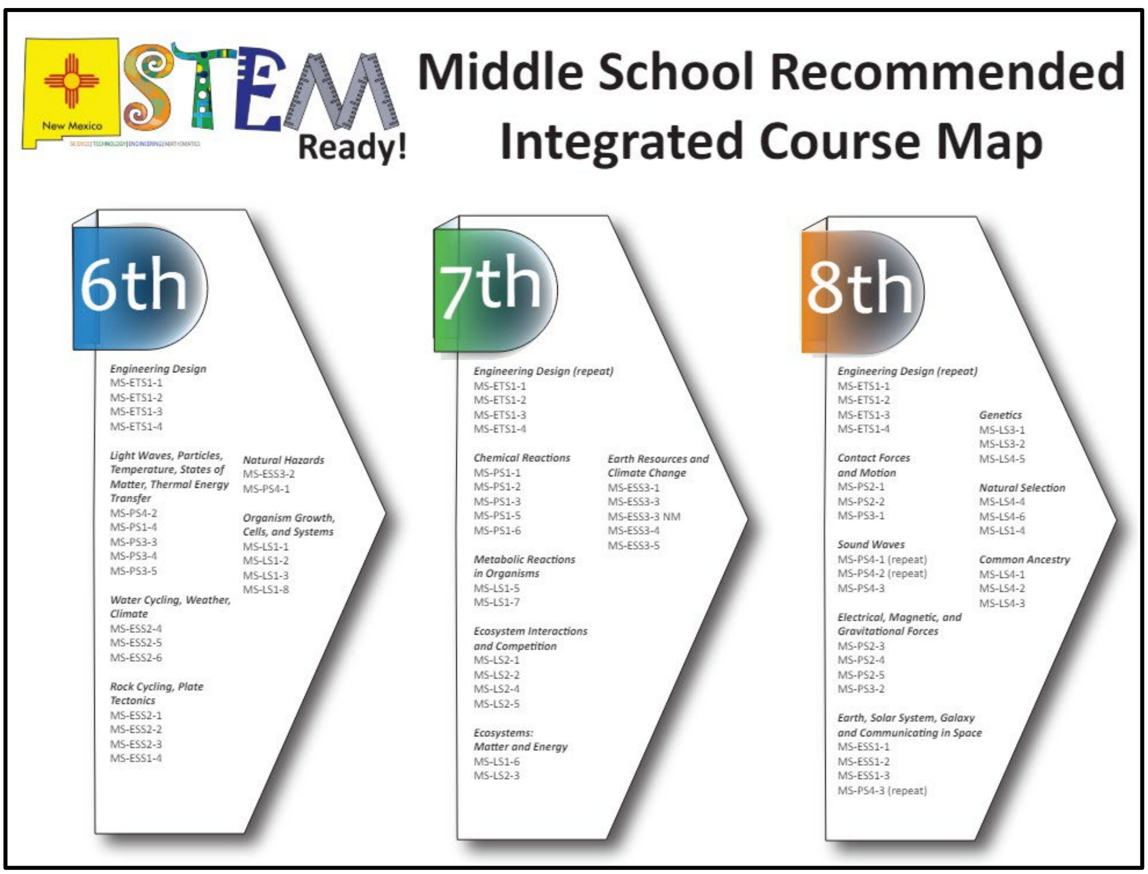
There are many public schools where high-quality instructional materials (HQIM) are present, and these should be used in the teaching of science. The updated 2.0 Instructional Scope includes some reference to the high-quality instructional materials (HQIM) used in the state, but also has updated sections that may be beneficial if they are not included with HQIM, like New Mexico relevant science phenomena and New Mexico's Multi-Layered Systems of Support (MLSS) section. It is recommended that schools with adopted HQIM continue to use their materials, but also reference the updated 2.0 Instructional Scope for context to better support New Mexico students.

New Mexico science teachers worked collaboratively to identify and construct an updated template, common misconceptions, sample phenomena, classroom assessment items, culturally and linguistically responsive (CLR) instructional strategies, Universal Design for Learning (UDL) strategies, MLSS, and cross-curricular connections 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 educational agencies (LEAs) should determine how best to bundle New Mexico STEM Ready! Science Standards based on their needs.

The standards are separated into their different disciplines and provided in a sequential format (EX: MS-PS1-1, MS-PS2-3, MS-ETS1-1), however, these standards are not meant to be taught individually on their own but bundled with other standards. Bundles are groups of standards arranged together to create endpoints for instruction and helps students see connections between concepts and allow more efficient use of instructional time. Work with your local school, or district, on creating bundles for your science courses or you can utilize resources and guidance from PED, such as the recommended discipline specific or integrated course maps (see images below).


New Mexico
STEM Ready!
Middle School Recommended
Discipline Specific Course Map
6th
Earth & Space Science Concentration
Engineering Design
MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
Earth's Place in the Universe
MS-ESS1-1
MS-ESS1-2
MS-ESS1-3
MS-ESS1-4
Earth's Systems
MS-ESS2-2
MS-ESS2-3
MS-ESS2-4
MS-ESS2-5
MS-ESS2-6
MS-ESS3-5
Biological Evolution
MS-LS4-1
MS-LS4-2
Matter and Its Interactions
MS-PS1-1
Motion and Stability: Forces and Interactions
MS-PS2-1
MS-PS2-2
7th
Life Science Concentration
Engineering Design (repeat)
MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
Earth's Systems
MS-ESS2-1
MS-ESS2-4(repeat)
Earth and Human Activity
MS-ESS3-1
Biological Evolution: Unity and Diversity
MS-LS4-3
MS-LS4-4
MS-LS4-5
MS-LS4-6
From Molecules to Organisms: Structure and Processes
MS-LS1-1
MS-LS1-2
MS-LS1-3
MS-LS1-4
MS-LS1-5
MS-LS1-6
MS-LS1-7
MS-LS1-8
Heredity: Inheritance and Variation of Traits
MS-LS3-1
MS-LS3-2
Ecosystems: Interactions, Energy, and Dynamics
MS-LS2-1
MS-LS2-2
MS-LS2-3
MS-LS2-4
MS-LS2-5
8th
Physical Science Concentration
Engineering Design (repeat)
MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
Earth and Human Activity
MS-ESS3-2
MS-ESS3-3
MS-ESS3-3 NM
MS-ESS3-4
Matter and Its Interactions
MS-PS1-2
MS-PS1-3
MS-PS1-4
MS-PS1-5
MS-PS1-6
Energy
MS-PS3-1
MS-PS3-2
MS-PS3-3
MS-PS3-4
MS-PS3-5
Motion and Stability: Forces and Interactions
MS-PS2-1(repeat)
MS-PS2-2(repeat)
MS-PS2-3
MS-PS2-4
MS-PS2-5
MS-PS1-1(repeat)
Waves and Their Applications in Technologies for Information Transfer
MS-PS4-1
MS-PS4-2
MS-PS4-3
Connections to Common Core math standards were considered in course map development.


New Mexico
STEM Ready!
Middle School Recommended
Integrated Course Map
6th
Engineering Design
MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
Light Waves, Particles, Temperature, States of Matter, Thermal Energy Transfer
MS-PS4-2
MS-PS1-4
MS-PS3-3
MS-PS3-4
MS-PS3-5
Water Cycling, Weather, Climate
MS-ESS2-4
MS-ESS2-5
MS-ESS2-6
Rock Cycling, Plate Tectonics
MS-ESS2-1
MS-ESS2-2
MS-ESS2-3
MS-ESS1-4
Natural Hazards
MS-ESS3-2
MS-PS4-1
Organism Growth, Cells, and Systems
MS-LS1-1
MS-LS1-2
MS-LS1-3
MS-LS1-8
7th
Engineering Design (repeat)
MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
Chemical Reactions
MS-PS1-1
MS-PS1-2
MS-PS1-3
MS-PS1-5
MS-PS1-6
Metabolic Reactions in Organisms
MS-LS1-5
MS-LS1-7
Ecosystem Interactions and Competition
MS-LS2-1
MS-LS2-2
MS-LS2-4
MS-LS2-5
Ecosystems: Matter and Energy
MS-LS1-6
MS-LS2-3
Earth Resources and Climate Change
MS-ESS3-1
MS-ESS3-3
MS-ESS3-3 NM
MS-ESS3-4
MS-ESS3-5
8th
Engineering Design (repeat)
MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
Contact Forces and Motion
MS-PS2-1
MS-PS2-2
MS-PS3-1
Sound Waves
MS-PS4-1 (repeat)
MS-PS4-2 (repeat)
MS-PS4-3
Electrical, Magnetic, and Gravitational Forces
MS-PS2-3
MS-PS2-4
MS-PS2-5
MS-PS3-2
Earth, Solar System, Galaxy and Communicating in Space
MS-ESS1-1
MS-ESS1-2
MS-ESS1-3
MS-PS4-3 (repeat)
Genetics
MS-LS3-1
MS-LS3-2
MS-LS4-5
Natural Selection
MS-LS4-4
MS-LS4-6
MS-LS1-4
Common Ancestry
MS-LS4-1
MS-LS4-2
MS-LS4-3

The Standards

Each performance expectation (PE) 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 (PE) 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 PE, contains the learning goals that students should achieve and that will be assessed using the PED. 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 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*

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.

Sample Phenomena and New Mexico Relevant Phenomena

Located directly under the standards and misconceptions are the suggested sample phenomena. This section was constructed specifically for New Mexico with suggestions for phenomena that are relevant to New Mexico or relatable by New Mexico students..

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

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

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

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

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

It is important that all students—including English 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.[2]

Classroom Assessment Items

To align with the phenomena section above, this includes New Mexico based assessment items that directly relate, or comparatively, to the suggested New Mexico phenomena when available.

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.[3]

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[4]:

- 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

[2] 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

[3] 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.

[4] 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.

[5] STEM Teaching Tools (n.d.), http://stemteachingtools.org/tools accessed on July 7, 2021

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 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 STEM Teaching Tools[5]: http://stemteachingtools.org/tools

- 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

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

[5] STEM Teaching Tools (n.d.), http://stemteachingtools.org/tools accessed on July 7, 2021

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. It is essential to recognize the impact of language in accessing the learning and guidance for linguistic vocabulary support are provided.

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[6].

- 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.

Multi Layered System of Supports (MLSS)

The Multi-Layered Systems of Support (MLSS) has been updated to include instructional, social-emotional, and behavioral supports for layers 1, 2, and 3. While not all supports can be listed to meet the needs of all students, general suggestions are provided for guidance. Work within your local control to best meet the needs of your students.

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, targeted supports (layer 2) for supporting those scholars that teachers identify as not understanding the topic, and students needing intensive support (layer 3) for those students needing longer duration or otherwise more

[6] STEM Teaching Tools (n.d.), http://stemteachingtools.org/tools accessed on July 7, 2021

intense support through small group instruction.

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.

Cross-Curricular Connections

The very last section of the Instructional Scope is the cross-curricular connections. These include math and literacy standards that are supplied for the performance expectation of each standard, as well as career connections for relevant job connections.

What: In order to provide guidance on cross-curricular instruction, the standards are identified for common core English language arts (ELA) and mathematics. 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?

Why: The cross-curricular connections utilizes common core ELA and mathematics standards identified in NGSS and provides suggestions for use within instruction so teachers are better able to see how these connections might live within their instruction.

How: When planning with your high-quality instructional materials (HQIM) use the suggested cross-curricular connections embedded in the sequence of instruction. If you do not have access to HQIM in your school, utilize the suggestions in this document that can be used in planning your instruction.

STANDARDS BREAKDOWN	
Heredity: Inheritance and Variation of Traits MS-LS3-1 MS-LS3-2	
Grade	**NGSS Discipline Overview**
MS	**Life Science**
Click to find the standards breakdown.	**Teacher Background by Performance Expectation (PE)**
LS3-1	Students will need to be able to develop a model in which they identify the relevant components for making sense of a given phenomenon involving the relationship between mutations and the effects on the organism, including genes, located on chromosomes, proteins, and traits of organisms. In their model, students will need to describe the relationships between components, including every gene has a certain structure, which determines the structure of a specific set of proteins, and protein structure influences protein function (e.g. the structure of some blood proteins allows them to attach to oxygen, the structure of a normal digestive protein allows it break down particular food molecules), and observable organism traits (e.g., structural, functional, behavioral) result from the activity of proteins. Students will need to be able to use the model to describe that structural changes to genes (i.e., mutations) may result in observable effects at the level of the organism, including why structural changes to genes may affect protein structure and function, may affect how proteins contribute to observable structures and functions in organisms and may result in trait changes that are beneficial, harmful, or neutral for the organism. Students will also need to use the model to describe that beneficial, neutral, or harmful changes to protein function can cause beneficial, neutral, or harmful changes in the structure and function of organisms.

Standards Breakdown

MS	Life Science 3-1			
LS3-1	*The performance expectation below was developed using the following elements from the NRC document, A Framework for K-12 Science Education*			
	MS-LS3-1: Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. **Clarification Statement:** Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins. **Assessment Boundary:** Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.	**SEP** **Developing and Using Models** • Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena.	**DCI** **LS3.A: Inheritance of Traits** • Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. **LS3.B: Variation of Traits** • In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.	**CCC** **Structure and Function** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.
	These standards are not meant to be taught individually on their own but bundled with other standards. Bundles are groups of standards arranged together to create endpoints for instruction, and it helps students see connections between concepts and allow more efficient use of instructional time. Work with your local school, or district, on creating bundles for your middle school science courses or you can utilize resources and guidance from NMPED.			
	Common Misconceptions			
	• Genes and proteins are the same thing. • Traits change due to the environment, which in turn changes genes. • The information in genes provides instructions for	• Genes are the sole determinants of traits • Single genes code for most traits • Dominant traits are the most common traits in a population • The limiting factor to getting	• All genetic tests are equally reliable and precise • Only certain people have "disease genes" • If a couple has a "one-in-four" risk of having a child with a disease, and their firstborn has the disease, the next three		

	rearranging chromosomes into traits. ● Mutations are always harmful to the functioning of an organism.	genetic information is the speed and/or cost of genome sequencing ● Once a mutation is discovered, it can be "fixed"	children will have a reduced risk. ● Only genetically modified food crops have genes. ● Your genes determine all of your characteristics, and cloned organisms are exact copies of the original.
	New Mexico Relevant 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 high quality instructional materials available.		
	Why are living things different from one another?	*Why do the animals at White Sands National Park look different than the same species in other parts of New Mexico?*	

	Encourage students to notice and wonder about photos of two cattle, one of whom has significantly more muscle than the other. The students then observe photos of other animals with similar differences in musculature: dogs, fish, rabbits, and mice. After developing initial models for the possible causes of these differences in musculature, students explore a collection of photos showing a range of visible differences. Sourced from Open Sci Ed 8.5 Genetics - OpenSciEd *What genetic and environmental factors led to the unique blue skin coloration of the Fugate family?* Using the text and/or video below, students will write their noticings and wonderings about the Fugate family of Kentucky. Students will research the Blue Fugate Family in Kentucky to show inheritance patterns in the family and link it back to a genetic mutation that changed the structure and function of the trait. Students will ask questions to determine the cause of the change in skin color (structure/function). Students will ask questions to determine how the change is inherited through the family. Text: The Fugate Family Of Kentucky Has Had Blue Skin For Centuries — Here's Why Video: Mystery of the Fugate Family: The Blue People of Kentucky	This New Mexico phenomenon is also used in LS4-4 and provides an example of bundling standards for students to see connections between concepts. Start a classroom discussion with students. Ask students if they've seen at home or in their area organisms or creatures such as lizards, mice, spiders, crickets, or rabbits. Continue questioning and ask what colors are the organisms that they've seen from the list. Do they blend in or camouflage with their environment? How does their coloring benefit or harm them in their environment?  Introduce students to the animals of White Sands National Park. Several species of animals have developed very specialized means of surviving in this harsh environment, enabling them to thrive in a place with very little surface water and highly mineralized groundwater. In fact, White Sands National Park is home to more than 800 different animal species, many of them nocturnal. Included in this number are species from all groups of the animal kingdom: mammals, reptiles, amphibians, birds, fish, and invertebrates. As they're looking at the site of animals, compile some notices and wonderings regarding what is the same and/or different from the initial discussion with what they've seen before. Animals - White Sands National Park (U.S. National Park Service)

How do moths produce sounds? What role do these sounds play in their survival and communication within their ecosystems?

Yponomeuta tymbal—the image of a tymbal showing a row of microtymbals. Credit: Hernaldo Mendoza Nava

Students will journal notices and wonderings from reading the online text. (Make sure students watch the slow-motion video of the moth creating sound.)

This question invites students to investigate the mechanisms behind ultrasonic sound production in moths, focusing on the biological structures and processes involved. It also encourages exploration of the ecological functions of these sounds, such as predator avoidance, mating communication, and navigation. By examining this phenomenon, students can gain insights into the complexities of animal behavior, sensory biology, and evolutionary adaptations that contribute to the survival of species within their natural habitats.

Adapted from: NMSTA Phenomenon Presentation

Classroom Assessment Items

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 high quality instructional materials available.

Goldfish Assessment

Goldfish are an important symbol in Chinese culture. Chinese people have been breeding goldfish for over 2,000 years. The type of fish they were bred from, the Asian carp, is normally gray, brown, or silver. But relatively rare mutations that produce red, orange, yellow, or no coloration in goldfish have been observed and recorded in China for at least 1,600 years. Research on goldfish breeding and genetics began over 100 years ago. Shisan C. Chen (1894–1957) was a Chinese geneticist who made some of the first discoveries of patterns in goldfish genetics.

Dr. Chen wrote a paper in 1928 titled "Transparency and Mottling, a Case of Mendelian Inheritance in the Goldfish Carassius Auratus" that described his experiments and results. *In his experiments, he had three different-looking goldfish (see drawings above), which he figured out were a result of whether their scales were transparent or reflective. In brown goldfish (A) the scales are reflective (you cannot see through them). Speckled goldfish (B) have some reflective and some transparent scales, and transparent goldfish (C) have all transparent scales.

Dr. Chen found that these variations in the trait of goldfish scales are passed from parents to offspring in predictable patterns.

Sourced from Open Sci Ed 8.5 Genetics - OpenSciEd

Hairless Xolos

The Mexican Hairless Dog or Xoloitzcuintli (Xolo) is an ancient breed of dog that traces its ancestry to the time of the Aztecs. It is the national breed of Mexico and a Xolo named Dante was recently

Effect of Global Climate Change on Gene Mutations

Task: Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in new traits that affect the characteristics and functions of an Arctic organism.

Background materials and exploration:
Adapted from: Adaptations of the Polar Bear
Arctic Fox Facts and Adaptations - Vulpes lagopus / Alopex lagopus
Ptarmigan May Be Tops in Adapting to Winter Weather | Audubon

Polar Bear Adaptations: Adaptation in a population of living things happens as a result of an adaptive trait. This is an inheritable trait that increases its survival rate so that it can live longer, reproduce longer, and have more offspring (that also have that trait). Adaptive traits can improve an animal's ability to find food, make a safer home, escape predators, and survive cold or heat or lack of water.

The polar bear has many adaptations for its life on the polar ice pack. Their white fur helps them hide in plain sight. This is a good thing as there are no trees or rocks to hide behind in their habitat. Blending in is the only way to hide. This adaptive trait is a physical adaptation.

They also are one of the only bears that have a totally carnivorous diet. This means that they eat only meat. Most bears are omnivores and also eat plant matter. But where polar bears live, there is almost no plant matter available, so they have adapted a totally carnivorous lifestyle. Their long, sharp claws help them pull seals right out of the water when they surface to breathe and onto the ice where the bears can feed.

Polar bears also have thick blubber and dense fur to featured in the Disney movie Coco. Not all Xolos are born hairless. Xolos that are born with hair are called coated Xolos.

1) Use data on the following pages to complete the questions in the table below.

What patterns do you see?		
Figures	Hairless Xolos	Coated Xolos
Figure 2		
Figure 3		
Figure 4		

Note: Additional figures on original source. For length and to provide context for the assessment item, not all figures were shown here.

2) Develop a model in the space below to explain the phenomenon of Coated and Hairless Xolos. Your model should include the following components: gene, chromosome, protein, trait, and organism.

Model: Draw a model that shows the important components and relationships in the phenomenon.	
Explanation: Use the model to describe how structural changes in the gene may result in observable effects.	

3) Is the mutant FOXI3 gene in Xolos beneficial, neutral, or harmful? Explain your thinking.

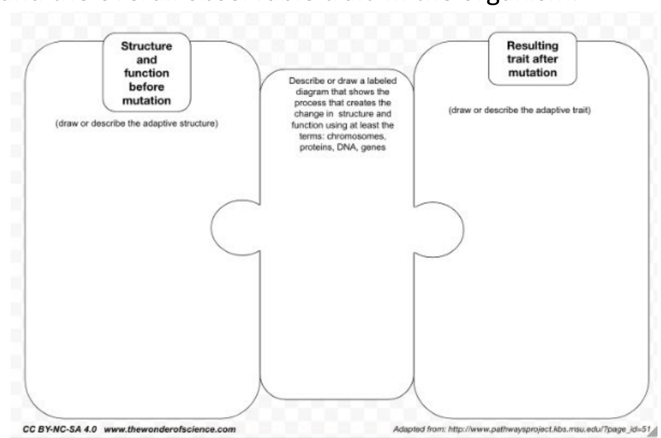
Sourced from Wonder of Science [MS-LS3-1 Assessment - Hairless Xolos]

help keep them warm. They have big, furry feet that act like snowshoes to help them walk on the snow. These are all physical adaptations that help polar bears survive in this environment.

Note: Additional readings on original source. For length and to provide context for the assessment item, not all readings were excerpted here.

1) Choose an organism from the background sources above, identify a specific mutation that has occurred in that organism, and explain why that mutation has had a harmful, beneficial, or neutral effect on the function of that organism.
Organism:
Mutation:
Explanation:

2) Using the organism and mutation from Question #1, fill in the flow chart and develop a model that illustrates the connection between a change in genetic structure and the overall observable trait in the organism.



3) Global climate change continues to put pressure on the health and survival of various Arctic organisms. If organisms are unable to respond in some manner to the warming climate, they could face endangerment and even extinction. Describe a potential genetic mutation that could benefit your focus organism as temperatures continue to rise and the Arctic environment continues to be impacted and changed.

Sourced from Wonder of Science [MS-LS3-1 Assessment - The Effect of Global Climate Change on Gene Mutations (NY)]

Culturally and Linguistically Responsive Instruction		
Validate and Affirm	*Build and Bridge*	*Linguistic Vocabulary Support*

Do you or your family have any unique characteristics? How are you alike or different from your birth parents? What are some strange things that organisms (like cats or dogs) have been born with? What knowledge and experiences have you had that might help us as a class explain why organisms can be born with unusual traits? What knowledge and experiences have you had that might help us as a class explain why some traits are passed from a birth mom to their child?	What questions do we need to answer to test your ideas about how characteristics can be passed down from birth parent to offspring? This can be a plant or animal. Why does this phenomenon matter to you, to your community, or to other scientists? Build a driving question board where students can stick questions and re- address their learning over time. Revisit this board often to help students make sense of their science learning. Bring those questions to group discussion.	Encourage students to work with vocabulary in meaningful ways. As students engage in sensemaking, students discuss complex ideas with everyday vocabulary and use many different verbal and non-verbal strategies to community their ideas. A common practice is to create an interactive "word wall" with students, with all the terms they have used when thinking and talking about the phenomena over the course of the unit. Overtime, teachers support, encourage, and/or require students to use proper terms as they ask questions, design experiments, and argue with evidence. Some vocabulary student build to include: chromosomes, genes, proteins, traits, mutations (harmful, beneficial, neutral), structure and function
Planning for Multi-Layer System of Support (MLSS) & Universal Design Learning		
Layer 1* *Core Instruction + Universal	***Layer 2* *Core + Targeted***	***Layer 3* *Core + Targeted + Intensive***
Instructional/Academic Supports		
Activate Background Knowledge: Information is more accessible and translated into learning when it is presented in a way that primes, activates, or provides pre-requisite knowledge. Be sure to supply or activate prior knowledge, like cell structures and function with DNA.	**Guide information processing and visualization:** Students will need multiple strategies and multiple entry points within the lesson to process and transfer their learning. Have visuals of some genetic changes that have happened and can be proved (a great example would be the Galapagos Finches' beaks that	Consider the misconceptions in content and skills needed within the PE and identify students for small group intervention. EX: The information in genes provides instructions for rearranging chromosomes into traits. **Language & Symbols:** Provide students with guided questions and sentence stems referencing Claim Evidence

	Representation: Pre-teach critical prerequisite concepts through demonstration or models like understanding how genes function before they can understand how they change. The teacher would begin by priming students with a discussion of genes and heredity and then ask the students what happens when something goes wrong with this process. Students should also model the life cycle of a protein to include mutations. They can model this in many different ways (skit, a picture, a video, a written explanation, etc. Have students practice making mRNA strands from a DNA code, reviewing information from prior lessons. Provide examples of harmful, beneficial, and neutral mutations. **Universal Design for Learning** [Representation] [Engagement] [Action and Expression] [STEM Ready UDL Supports]	have changed shapes since people have started watching them). Discuss the reason for the changes. Include pictures of the islands during the drought years so that students can see the island's change in vegetation. In small groups, students model protein synthesis with their mRNA strand and analyze what amino acids are in the protein that was just formed. Then go back to the original DNA strand, but this time it will have a mutation, and have them make their mRNA. Following the same steps as before, students will make the protein with the mRNA strand. They should then make comparisons from the original protein to the one with a mutation. Then individually apply this information to the concept that a change in the chromosome affected the protein and how would this in turn affect function.	Reasoning (CER). ___causes __. __is the reason for __. From the __investigation, evidence to support the claim is __. In the data__… This claim is evidenced by__… According to the data/observations collected during the investigation__… This is important because __… A logical conclusion that can be drawn from this evidence is that __because __. This evidence shows/suggests/confirms that __.
	Social Emotional Supports		

	Integrate CASEL Playbook Strategies into your whole class routines or instruction. Some emphasized strategies/suggested activities are: It is important to remember that not all students in your classroom may be living with, or even know, either of their biological parents. Explicitly recognize that human families are created in a variety of ways that are not just biological and acknowledge the validity of all kinds of human families. As you strive to make your classroom inclusive and accessible for all students, you will want to consider the language that you and your students use to discuss the relationships of the cattle in the pedigrees you're exploring. Use nongender terms such as "parent," "offspring," and "sibling" whenever possible. You might specify "female parent" and "male parent" as needed to keep the focus on biological relationships.	**Responsible Decision Making/Problem Solving/Relationship Skills:** After students create their models, utilize the Gallery Walk (p.27) to have them view each other's work. Provide small-group support for students in need of focused skill instruction related to self-awareness, self-management, social awareness, relationship skills, and responsible decision making. Increase positive reinforcement within the classroom for positive behavior.	Ensure that all learning environments allow students to thrive by considering the PBIS Sensory Tools. Develop consistent Behavior Meetings to help build consistency and support for the students. Additional student stakeholders may offer additional support through Counselor Referral or Collaboration with a student's physician or mental health provider.
	Behavioral Supports		
	For all students, the use of Clear, consistent, and predictable consequences helps build a productive learning environment. Ensure the use of a PBIS Behavior Contract during lab investigations and hands-on learning to ensure Layer 1 routines are supported.	Ensure the use of a PBIS Behavior Contract during lab investigations and hands-on learning to ensure Layer 1 routines are supported. With challenging academic learning, utilize PBIS Structured Breaks throughout the learning cycle to support the multi-sensory environment of phenomena-based science.	Utilize the PBIS Check In Check Out (CICO) to engage all student stakeholders in creating a consistent learning environment.
	Cross-Curricular Connections		
	ELA/Literacy	*Mathematics*	

	RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-LS3-1) **RST.6-8.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics. (MS-LS3-1) **RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-LS3-1) **SL.8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence and add interest. (MS-LS3-1) --- Students can research the concept of mutations and their effects on proteins. They can then use this research to build a model that explains the connection. This model can be a drawing, diagram, or even a simple animation. As they build the model, students should cite specific passages from their research that support the different steps or components of the model. Before building their models, have students create a glossary of scientific terms with definitions (e.g., mutations, genes, chromosomes). Encourage them to refer to their glossary while building models. Students can create a multimedia presentation that explains their model. This presentation can include the model itself, alongside text explaining each step. They can also integrate visuals from their research, like diagrams of chromosomes or protein structures.	None listed

	Career & Skill Connections	
	Animal training Anthropology Astronomy Atmospheric Science Biology Chemistry Conservation Science Engineering Environmental Economist	Farming Landscape architecture & design Mechanical engineering Meteorology Solar energy systems engineering Transportation management Urban planning

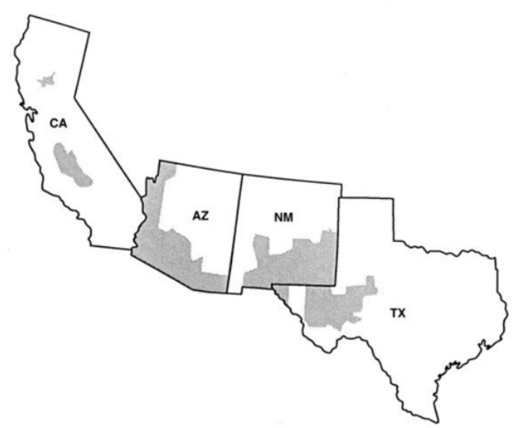
Grade	NGSS Discipline Overview
MS	**Life Science**
Click to find the standards breakdown.	**Teacher Background by Performance Expectation (PE)**
LS3-2	Students will need to develop a model (e.g., Punnett squares, diagrams, simulations) for a given phenomenon involving the differences in genetic variation that arise from sexual and asexual reproduction. In the model, students identify and describe the relevant components of chromosome pairs, including genetic variants, in sexual and asexual reproduction for parents and offspring. Students will need to be able to describe the relationships between components, including that during reproduction (both sexual and asexual), parents transfer genetic information in the form of genes to their offspring, and under normal conditions, offspring have the same number of chromosomes, and therefore genes, as their parents. They will also need to describe that during asexual reproduction, a single parent's chromosomes (one set) are the source of genetic material in the offspring, and during sexual reproduction, two parents (two sets of chromosomes) contribute genetic material to the offspring. Students will need to use the model to describe a causal account for why sexual and asexual reproduction result in different amounts of genetic variation in offspring relative to their parents, including that in asexual reproduction offspring have a single source of genetic information, and their chromosomes are complete copies of each single parent pair of chromosomes, and offspring chromosomes are identical to parent chromosomes. They will also need to describe that in sexual reproduction offspring have two sources of genetic information (i.e., two sets of chromosomes) that contribute to each final pair of chromosomes in the offspring and that because both parents are likely to contribute different genetic information, offspring chromosomes reflect a combination of genetic material from two sources and therefore contain new combinations of genes (genetic variation) that make offspring chromosomes distinct from those of either parent. Students will need to be able to use cause-and-effect relationships found in the model between the type of reproduction and the resulting genetic variation to predict that more genetic variation occurs in organisms that reproduce sexually compared to organisms that reproduce asexually.

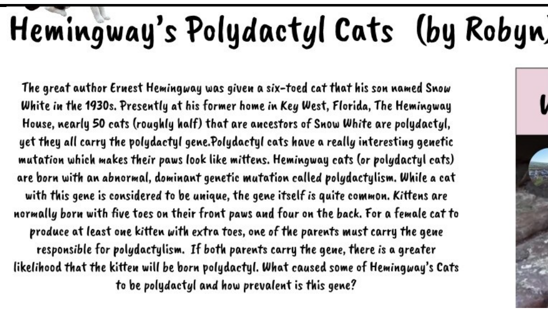
Standards Breakdown				
MS	[Life Science 3-2](#)			
LS3-2	*The performance expectation below was developed using the following elements from the NRC document, A Framework for K-12 Science Education*			
	MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. **Clarification Statement:** Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation. **Assessment Boundary:** None	**SEP** **Developing and Using Models** Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena.	**DCI** **LS1.B: Growth and Development of Organisms** • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary) **LS3.A: Inheritance of Traits** • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **LS3.B: Variation of Traits** • In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.	**CCC** **Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural systems.
	These standards are not meant to be taught individually on their own but bundled with other standards. Bundles are groups of standards arranged together to create endpoints for instruction, and it helps students see connections between concepts and allow more efficient use of instructional time. Work with your local school, or district, on creating bundles for your middle school science courses or you can utilize resources and guidance from [NMPED](#).			
	Common Misconceptions			

• Sexual reproduction always involves mating. (False. Sexual reproduction also occurs in other ways, such as conjugation in bacteria and cross-pollination in plants.) • Sexual reproduction is always advantageous over asexual reproduction. • All organisms reproduce in the same way.	• Plants do not reproduce sexually. (False. Many plants reproduce sexually. In flowering plants, pollen is the male gamete, and an egg is the female gamete.) • Asexual reproduction occurs only in microorganisms. (False. Plants and fungi may also reproduce asexually.)	• Sexual reproduction is not necessarily "better" than asexual reproduction, or vice versa. • Although sexual reproduction requires two parents, they do not always have to be two separate individuals. • Asexual reproduction is only done by bacteria. • Genetic variation in offspring cannot be predicted.

New Mexico Relevant 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 high quality instructional materials available.

Why are living things different from one another?	*How do New Mexico pecan trees reproduce and why is New Mexico a good place to grow pecans?*
This HQIM phenomenon is also used in LS1-5 and provides an example of bundling standards for students to see connections between concepts. Students notice and wonder about photos of two cattle, one of whom has significantly more muscle than the other. The students then observe photos of other animals with similar differences in musculature: dogs, fish, rabbits, and mice. After developing initial models for the possible causes of these differences in musculature, students explore a collection of photos showing a range of visible differences. Sourced from Open Sci Ed [8.5 Genetics - OpenSciEd] *How can a Punnett Square be used to model potential offspring?*	 Figure 1. Western pecan growing region. The image above represents the growing areas of pecans in the western United States. The world's largest pecan orchard is located in Mesilla, New Mexico at Stalman's Farms. (NMSU Publications) Use the videos and text to have students generate notices and wonders about New Mexico pecans. The historical text from NMSU gives the nearly 100 year history of pecans in New Mexico and includes



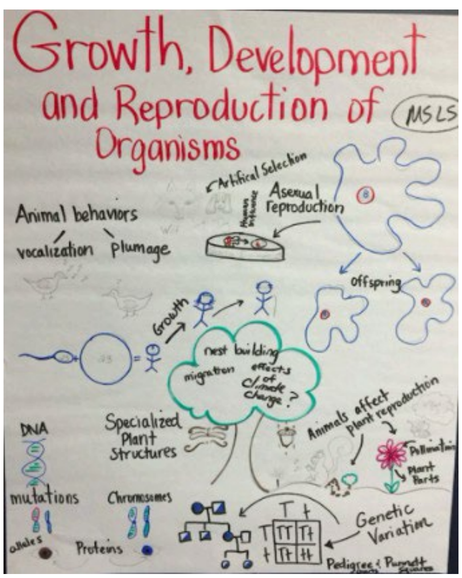
Hemingway's Polydactyl Cats (by Robyn

The great author Ernest Hemingway was given a six-toed cat that his son named Snow White in the 1930s. Presently at his former home in Key West, Florida, The Hemingway House, nearly 50 cats (roughly half) that are ancestors of Snow White are polydactyl, yet they all carry the polydactyl gene.Polydactyl cats have a really interesting genetic mutation which makes their paws look like mittens. Hemingway cats (or polydactyl cats) are born with an abnormal, dominant genetic mutation called polydactylism. While a cat with this gene is considered to be unique, the gene itself is quite common. Kittens are normally born with five toes on their front paws and four on the back. For a female cat to produce at least one kitten with extra toes, one of the parents must carry the gene responsible for polydactylism. If both parents carry the gene, there is a greater likelihood that the kitten will be born polydactyl. What caused some of Hemingway's Cats to be polydactyl and how prevalent is this gene?

Students will watch the video to write noticings and wonderings. Students will be able to construct an explanation that determines the difference between dominant and recessive alleles and explore how they are expressed in offspring by completing Hemingway's cat activity.

What does the Anchor Chart have to do with growth, development, and reproduction of organisms?

Using the Anchor Chart, students will write noticings and wonderings about the information on the anchor chart. Students can do a pair-share, group share, and class share through a gallery walk documenting their thinking.



Adapted from The Wonder of Science Storyline
MS Unit - Heredity, Repro and Growth Storyline (MS-LS1-4, MS-LS1-5, MS-LS3-2)

information on reproduction.

Videos:
Celebrate New Mexico: Pecan Orchards
How do pecans grow? Reproductive clip at 6:24

Text:
Historical Background of Pecan Plantings in the Western Region
A tough nut to crack: NMSU leads in national effort to map the pecan genome

Classroom Assessment Items

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 high quality instructional materials available.

Goldfish Assessment

Name: ______________________________ Date: ______________

Goldfish Assessment

A. Brown goldfish B. Speckled goldfish C. Transparent goldfish

Goldfish are an important symbol in Chinese culture. Chinese people have been breeding goldfish for over 2,000 years. The type of fish they were bred from, the Asian carp, is normally gray, brown, or silver. But relatively rare mutations that produce red, orange, yellow, or no coloration in goldfish have been observed and recorded in China for at least 1,600 years. Research on goldfish breeding and genetics began over 100 years ago. Shisan C. Chen (1894–1957) was a Chinese geneticist who made some of the first discoveries of patterns in goldfish genetics.

Dr. Chen wrote a paper in 1928 titled "Transparency and Mottling, a Case of Mendelian Inheritance in the Goldfish *Carassius Auratus*" that described his experiments and results.* In his experiments, he had three different-looking goldfish (see drawings above), which he figured out were a result of whether their scales were transparent or reflective. In brown goldfish (A) the scales are reflective (you cannot see through them). Speckled goldfish (B) have some reflective and some transparent scales, and transparent goldfish (C) have all transparent scales.

Dr. Chen found that these variations in the trait of goldfish scales are passed from parents to offspring in predictable patterns. Here is a summary of the main results from Dr. Chen's paper:

Brown goldfish. I made matings between females and males of the brown goldfish. The offspring of these matings consisted of only brown goldfish (drawing A).

Transparent fish. I made nine matings between female and male transparent fish. These nine matings produced many thousands of offspring, and all of them were transparent fish (drawing C).

Breeding transparent fish with brown fish. I made ten matings between transparent females and brown males and ten matings between brown females and transparent males. All these matings produced only fish with a speckled pattern (drawing B).

Breeding speckled fish with speckled fish. I made seven matings between female and male speckled fish. The results of these matings show that among the offspring there were always about ¼ transparent fish, ½ speckled fish, and ¼ brown fish.

1a. Synthesize the data using the Checklist for Obtaining and Evaluating Information from Scientific Text to make sense of and evaluate the information in the reading.

Bananas

In the questions that follow, you will create and use a model to explain how sexual and asexual reproduction affect the survival of bananas.

Reading 1 - Changes in Bananas
(Adapted from: Bananas Looked totally different in the 1940s — before disaster struck)

Wild bananas make hard seeds that aren't good to eat. In nature, bananas reproduce by using sperm cells created inside pollen. This pollen lands on the female part of a flower. The pollen then fertilizes the plant's egg cell. This creates a seed that contains the offspring, and the flower develops into a fruit. Unfortunately for humans, most of the bananas that reproduce in this way are not good to eat.

Some bananas, like the ones you see at the grocery store, are edible. Humans grew the edible bananas they found and created a variety called the Cavendish banana, which is the most-eaten banana in the world. However, this banana does not have seeds and can't reproduce on its own. This means the only way to keep growing these bananas is to use cuttings or clones from a single parent plant. Unfortunately, these bananas are at risk of dying out. The problem is a type of fungus that infects the roots of a banana tree and keeps the plant from taking in nutrients and water. This fungus has

1b. Using the information you obtained from the reading, visually represent each mating in Dr. Chen's scientific paper created 4 pedigrees, one of each mating he did in his experiment. Make four offspring for each mating. Be sure to include a key for phenotype and genotype in your pedigree.

1c. In 1928, when Dr. Chen did research on goldfish, scientists did not yet know about genetic material, proteins, and phenotypes. Write or draw a model that explains how the transparent fish's phenotype is influenced by its genotype, starting with how that fish got its genotype and including a protein. Also, include an example of the brown fish for comparison. Be sure to indicate cause-effect relationships in your model and/or explanation.

2a. Speckled goldfish are popular fish because of their beautiful colors. If a goldfish breeder wanted to breed speckled fish, should the breeder mate a speckled female with a speckled male or a brown female with a transparent male? Which breeding combination would you recommend and why? Use Punnett squares or probability calculations showing the potential outcomes of each mating to support your answer.

2b. Use words and/or drawings to show how the offspring's genotype results from the parents' chromosomes. (You may or may not explain this cause-effect relationship using your Punnett square or your math work.)

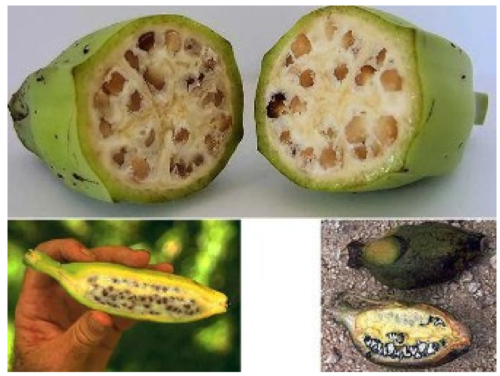
3. (This item will not be scored.) The goldfish breeder kept two specked siblings (both from the same parents) in two different environments. The breeder noticed that the fishes' scale colors stayed the same in these different environments, but their size was different: one was significantly larger than the other. Predict three possible environmental factors that could influence the size variation between these two goldfish.

Sourced from Open Sci Ed Lesson 10 [8.5 Genetics - OpenSciEd]

The Honeycrisp

already wiped out one banana variety, the Gros Michel, which used to be the most popular banana. Bananas have a gene called RGA2 that makes them resistant to the fungus. This gene can be either active (represented by the allele A) and resistant to the fungus or inactive (represented by the allele a) and not resistant. Cavendish bananas typically have the inactive form of the gene and can't resist the fungus.

Figure 1 - Wild bananas have large, inedible seeds



This image shows wild bananas with large, inedible seeds.

Figure 2- Cavendish bananas on their way to the grocery store

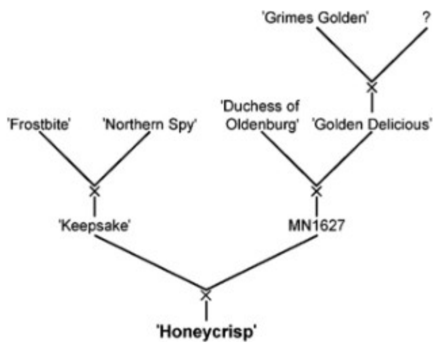
This image shows cavendish bananas on their way to the grocery store.

Question 1: Complete the sentence below based on the information in Reading 1.
-Wild bananas reproduce _(asexually/sexually) _, which means they have _(more/less) _ genetic diversity.

Question 2: Complete the sentence below based on the information in Reading 1.
-Cavendish bananas reproduce _(asexually/sexually) _, which means they have _(more/less) _ genetic diversity.

The Honeycrisp (Malus pumila) is a cultivated variety of apples developed by David Bedford at the University of Minnesota, Twin Cities. Dr. Bedford and his team spent nearly 30 years of selective breeding to create this delicious and expensive variety. Watch the YouTube video [Have We Engineered the Perfect Apple?](#) for background information on the genetics of the Honeycrisp.

Dr. Bedford and his team used DNA testing to determine the pedigree shown below.



1) Circle and identify the following on the pedigree: parents, grandparents, and great-grandparents of the Honeycrisp.

Apple Genetics:

- Tartness is recessive (Frostbite's genotype is TT, MN1627's genotype is Tt)
- Sweetness is recessive (Golden Delicious' genotype is ss, Keepsake's genotype is Ss)
- Juiciness is dominant (Honeycrisp's genotype is TT, MN1627's genotype is Tt)
- Crunchiness is dominant (Keepsake's genotype is Tt, MN1627's genotype is tt)
- Red skin coloring is dominant (The Keepsake and MN1627 are both red apples)
- Thick skin is dominant (The Keepsake's genotype is Kk, Golden Delicious is KK)

The Honeycrisp apple, pictured above, is both crunchy and juicy. The apple also has a very sweet-tart flavor profile. The Honeycrisp has a

Question 3: Complete the sentence below based on the information in Reading 1.
-The wild bananas with the active genes (AA)
(would/would not) be protected against the fungus.
-The Cavendish bananas with the inactive genes (aa) (would/would not) be protected against the fungus.

Question 4: Fill in the Punnett square for wild banana reproduction.

A. Female: Aa
B. Male: Aa

	Female	
Male		

Question 5: Using your Punnett square to help you, draw a model of reproduction in wild bananas. Your model should show:

A. Number of banana parents
B. Chromosomes (alleles) of the parent(s)
C. Chromosomes (alleles) of four offspring

Question 6: Draw a model of reproduction in Cavendish bananas. Your model should show:

A. Number of banana parents
B. Chromosomes (alleles) of the parent(s)
C. Chromosomes (alleles) of four offspring

Use this key to help with your model:	
Banana parent	
Dominant allele	A
Recessive allele	a

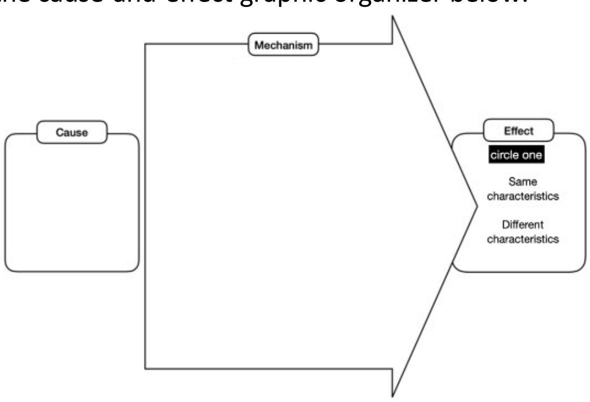
Question 7: Using your Punnett square and your models, explain why Cavendish bananas are at risk of dying out,

very thin skin and is easily punctured.

Develop a model in the table space (e.g., Punnett squares, diagrams, etc.) that explains how the Honeycrisp received its characteristic structure, color, and flavor through sexual reproduction. Your model should include parents, offspring, and chromosome pairs.
The first Honeycrisp apple was created in 1974. Clones of this variety have been created by grafting a shoot from the living tree onto a living root.

3) In the space below, develop a model (e.g., Punnett squares, diagrams, etc.) that explains how the Honeycrisp found in supermarkets today is as crispy and juicy as that original apple from 1974. Note: the process of plant cloning is a form of asexual reproduction.

4) If you plant a seed from a Honeycrisp apple you buy in the grocery store, will it produce apples that have the same characteristics as the apple you bought? Explain your thinking using the cause-and-effect graphic organizer below.



Sourced from Wonder of Science [MS-LS3-2 Assessment - The Honeycrisp]

but wild bananas are less likely. Idea bank: sexual, asexual, variation, cause/effect

Sourced from SEEd [Bananas- SEEd 7.4.1 Formative Assessment]

Culturally and Linguistically Responsive Instruction		
Validate and Affirm	*Build and Bridge*	*Linguistic Vocabulary Support*
What are the similarities and differences between you and your family? What are some ways that plants reproduce? What are some ways that other organisms reproduce? What knowledge and experiences have you had that might help us as a class explain the similarities and differences between asexually reproduced plant parents and their offspring? Like ivy plants or potato plants. What knowledge and experiences have you had that might help us as a class explain the similarities and differences between sexually reproduced parents and their offspring? like apple trees, dogs, cats, or grape plants.	What questions do we need to answer to test your ideas about why some offspring look identical to their parents and some look different? Why does this phenomenon matter to you, to your community, or to other scientists? Build a driving question board where students can stick questions and re- address their learning over time. Revisit this board often to help students make sense of their science learning. Bring those questions to group discussion.	Starting with the phenomenon discussion, and throughout the remainder of instruction, utilize language support sentence frames to support language learners during discussion. I think ____because ____. An example of _____is _____. The reason why is _____. I agree with you because _____. I disagree with you because ____. Create a large anchor chart out of poster paper, or cardboard, in the form of a Punnett square, pedigree chart, or other similar graphic organizers that could model genetics. Throughout the learning process, have students summarize on an index card or piece of paper that can be pinned to the correct place on the organizer. Encourage students to work with vocabulary in meaningful ways. As students engage in sensemaking, students discuss complex ideas with everyday vocabulary and use many different verbal and non-verbal strategies to community their ideas. A common practice is to create an interactive "word wall" with students, with all the terms they have used when thinking and talking about the phenomena over the course of the unit. Overtime, teachers support, encourage, and/or require students to use proper terms as they ask questions, design experiments, and argue with evidence. Some vocabulary student build to include: chromosome, allele, homozygous, heterozygous, DNA, Punnett square, sexual reproduction, asexual reproduction, parent cell, daughter cell, budding, fragmentation, parthenogenesis, binary fission, spores,

		mutation, offspring
Planning for Multi-Layer System of Support (MLSS) & Universal Design Learning		
Layer 1 ***Core Instruction + Universal***	***Layer 2*** ***Core + Targeted***	***Layer 3*** ***Core + Targeted + Intensive***
Instructional/Academic Supports		
Comprehension: Provide multiple real-world, local community applications of science investigations, including having students complete a simulation investigation on pollinating flowers. Make sure to explain why the pollen needs to touch the stigma, and what this will accomplish for the plant. Have some plants that do not get pollinated and some that do. compare and contrast the results. Have plants like the golden pothos that are hard to kill and reproduce asexually. **Guide information processing and visualization:** Students will need multiple strategies and multiple entry points within the lesson to process and transfer their learning. Have students compare and contrast the way that various organisms, both plants and animals, reproduce. **Universal Design for Learning** [Representation] [Engagement] [Action and Expression] [STEM Ready UDL Supports]	Have pictures of many plants that reproduce asexually (i.e., potatoes, garlic, pothos or devil's ivy). Have students draw a model of how these plants reproduce. Then draw a model of a plant that reproduces sexually (e.g., corn or sunflowers) with models showing how these plants reproduce.	Consider the misconceptions in content and skills needed within the PE and identify students for small group intervention. **Maximize Transfer and Generalization:** All learners can benefit from assistance in how to transfer the information to new situations as learning is not about individual facts in isolation. When discussing asexual and sexual reproduction work with students to create checklists or organizers on characteristics to look for in comparing examples. Create card sorts for students to match pictures of plants to the method of reproduction. Any time students make a match, encourage students to justify with evidence from their learning.
Social Emotional Supports		

	Integrate CASEL Playbook Strategies into your whole class routines or instruction. Some emphasized strategies/suggested activities are: **Self/Social Awareness:** After introducing the phenomenon, utilize the Optimistic Closure-Human Bar Graph (p.39) for their current understanding of the phenomenon or questions. **Responsible Decision Making/Problem Solving/Relationship Skills:** After students create their models, utilize the Gallery Walk (p.27) to have them view each other's work.	Provide small-group support for students in need of focused skill instruction related to self-awareness, self-management, social awareness, relationship skills, and responsible decision making. Increase positive reinforcement within the classroom for positive behavior.	Ensure that all learning environments allow students to thrive by considering the PBIS Sensory Tools. Develop consistent Behavior Meetings to help build consistency and support for the students. Additional student stakeholders may offer additional support through Counselor Referral or Collaboration with a student's physician or mental health provider.
	Behavioral Supports		
	For all students, the use of Clear, consistent, and predictable consequences helps build a productive learning environment. Ensure the use of a PBIS Behavior Contract during lab investigations and hands-on learning to ensure Layer 1 routines are supported.	Ensure the use of a PBIS Behavior Contract during lab investigations and hands-on learning to ensure Layer 1 routines are supported. With challenging academic learning, utilize PBIS Structured Breaks throughout the learning cycle to support the multi-sensory environment of phenomena-based science.	Utilize the PBIS Check In Check Out (CICO) to engage all student stakeholders in creating a consistent learning environment.

Cross-Curricular Connections	
ELA/Literacy	*Mathematics*
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-LS3-2) **RST.6-8.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics. (MS-LS3-2) **RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-LS3-2) **SL.8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.(MS-LS3-2)	**MP.4** Model with mathematics. (MS-LS3-2) **6.SP.B.5** Summarize numerical data sets in relation to their context. (MS-LS3-2)
Students can research the concepts of asexual and sexual reproduction and their outcomes on genetic information. They can then use this research to build a model that compares these two processes. As they build the model, students should cite specific passages from their research that support the distinction between asexual and sexual reproduction, and the resulting genetic variation. Before building their models, have the students create a glossary of scientific terms with definitions (e.g., sexual production, asexual production, variation, genetic information). Encourage them to refer back to their glossary while building models. Students can create a multimedia presentation that explains a side-by-side comparison model of sexual v. asexual reproduction model. They can also integrate visuals from their research, like diagrams or animations showing the process of mitosis and meiosis.	Students can develop a mathematical model to represent the probability of genetic variation in offspring from sexual reproduction. This could involve assigning probabilities to different chromosome combinations during meiosis using Punnett squares and simulating random chromosome combinations using dice or spinners to represent the chance of getting different alleles in offspring. They can then analyze their data by calculating the percentage of offspring with different genetic variations or creating charts or graphs to represent the probability distribution of different genotypes in offspring. Students could also engage in mathematical modeling and data analysis about offspring characteristics (e.g., the average number of offspring produced by different organisms using asexual and sexual reproduction) or asexual reproduction efficiency (e.g., calculating the time it takes for an organism to reproduce asexually compared to the time it takes for sexual reproduction).

Career & Skill Connections	
Animal training Anthropology Astronomy Atmospheric Science Biology Chemistry Conservation Science Engineering Environmental economist	Farming Landscape architecture & design Mechanical engineering Meteorology Solar energy systems engineering Transportation management Urban planning

Section 3 – Planning Resources

Overview

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[1]. 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 [2]. 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. 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. 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.

Getting Started with Using the Standards

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.

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[3]:

- 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

[1] 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.

[2] 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.

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

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?
- 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 aspects of instruction considerations that can be used to assist with this process.

- Create or utilize the summative assessment and check its alignment with the performance expectation.

Engaging in the Science and Engineering Practices

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. 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.
    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 has 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.

Using science investigations to develop caring practices for social-ecological systems – STEM Teaching Tool #61

Science investigations are a powerful way to foster caring practices for social-ecological systems. It encourages building relationships between learners and local ecosystems, highlighting the importance of multispecies justice and interconnectedness. The approach integrates diverse cultural perspectives, promotes empathy and ethical considerations, and supports transdisciplinary inquiry-based learning. Educators are urged to create opportunities for students to engage with their environment through observation, inquiry, and actions that benefit both humans and more-than-humans.

How to integrate the argumentation from evidence practice into engineering design projects – STEM Teaching Tool #63

The practice brief explains how to integrate argumentation from evidence into engineering design projects. It highlights the importance of teaching students to support engineering claims with specific evidence and reasoning, aligning with scientific practices. This process involves evaluating design merits, using diverse forms of evidence, and fostering collaborative problem-solving. The brief also addresses equity, suggesting accommodations to ensure all students can engage in argumentation, and provides actionable strategies for educators to create robust, argument-driven engineering projects.

How can arguing from evidence support sensemaking in elementary science? – STEM Teaching Tool #72

The practice brief focuses on the importance of integrating argumentation from evidence into elementary science education to support sensemaking. It highlights the need for students to engage in evidence-based discussions, propose and critique claims, and collaboratively build explanations for phenomena. The brief emphasizes creating equitable learning environments where diverse perspectives are valued and students develop skills in scientific reasoning. It also provides practical strategies for educators to foster a classroom culture that supports inquiry, curiosity, and the development of critical thinking skills.

Crosscutting concepts

A Framework for K-12 Science 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. 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.](http://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.

Why you should stop pre-teaching science vocabulary and focus on students developing conceptual meeting first – STEM Teaching Tool #66

> In New Mexico, and in the *Framework for K–12 Science Education,* we promote an inclusive educational environment for all students. Students should first develop conceptual understanding through sensemaking and observation. It is important to leverage students' home languages and diverse communication methods to enhance learning and participation, especially for multilingual and historically marginalized students. The approach promotes linguistic equity, encouraging environments where all forms of communication are valued, and suggests practical strategies for educators to integrate this methodology into their teaching practices.

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.

Supporting observations, wonderings, systems thinking & "Should We" deliberations through Learning in Places - STEM Teaching Tool #82

The practice brief emphasizes the importance of integrating observations, wonderings, and systems thinking in science education to support socioecological understanding and ethical decision-making. It advocates for field-based practices where learners and families engage with their environments, ask meaningful questions, and consider ethical implications. This approach values diverse cultural perspectives and aims to create equitable, place-based learning experiences that connect science with community well-being.

Identifying local environmental justice, phenomena for science and engineering investigations - STEM Teaching Tool #87

The practice brief highlights the need for science and engineering education to focus on local environmental justice (EJ) issues. It encourages engaging students with personally relevant EJ phenomena to develop a deeper understanding of these issues and to promote civic action. By investigating local EJ concerns, students can explore causes, impacts, and diverse perspectives, fostering individual and collective agency. The brief also emphasizes the importance of community-based learning and the integration of interdisciplinary approaches to address EJ and support frontline communities.

UDL: Action and Expression

- Provide independent think time before students engage with others or responses are discussed.
- Ensure students have enough time to complete tasks and provide extra time if needed.
- Provide access to pre-cut materials, assistive tools, devices, and software.
- Offer flexibility and choice with the ways students demonstrate and communicate their understanding.
- Invite students to explain their thinking verbally or nonverbally with manipulatives, drawings, diagrams.
- Support fluency with graduated levels of support or practice.
- Apply and gradually release scaffolds to support independent learning.
- Support discourse with sentence frames or visible language displays.
- Support the development of organizational skills in problem-solving with access to templates, rubrics, and checklists.
- Post visible goals, objectives, and schedules.
- Provide opportunities for self-assessment and enable students to monitor their own progress.

Throughout the curriculum, students should be invited to share both their understanding and their reasoning about mathematical ideas with others. Offer flexibility and choice with the ways students demonstrate and communicate their understanding and invite students to explain their thinking verbally or nonverbally with manipulatives, drawings, diagrams. Provide independent think time before students engage with others or responses are discussed and support discourse with sentence frames or visible language displays. Ensure students have enough time to complete tasks and provide extra time if needed, as well as pre-cut materials, assistive tools, devices, and software. Support fluency with graduated levels of support or practice, applying and gradually releasing scaffolds to support independent learning. Support the development of organizational skills in problem-solving with access to templates, rubrics, and checklists and provide opportunities for self-assessment and enable students to monitor their own progress. Post visible goals, objectives, and schedules.

UDL: Engagement

- Provide choice by inviting students to decide which problem to start with, select a subset of problems to complete, which strategy to use, the order they complete a task, etc.
- Provide access to a variety of tools or materials.
- Leverage curiosity and students' existing interests and invite students to name connections to their own lived experiences.
- Use visible timers and alerts to prepare for transitions.
- Chunk tasks into more manageable parts and check in with students to provide feedback and encouragement after each chunk.
- Differentiate the degree of difficulty or complexity by starting with accessible values.
- Periodically revisit community norms and provide group feedback that encourages collaboration and community.
- Provide ongoing feedback that helps students maintain sustained effort and persistence during a task.
- Encourage self-reflection and identification of personal goals.
- Provide access to tools and strategies designed to help students self-motivate and become more independent.

Students' attitudes, interests, and values help to determine the ways in which they are most engaged and motivated to learn. Provide access to a variety of tools, strategies, and materials designed to help students self-motivate and become more independent. Leverage curiosity and students' existing interests and invite students to name connections to their own lived experiences. Provide choice by inviting students to decide which problem to start with, select a subset of problems to complete, which strategy to use, the order they complete a task, etc. Use visible timers and alerts to prepare for transitions, and chunk tasks into more manageable parts and check in with students to provide feedback and encouragement after each chunk. Differentiate the degree of difficulty or complexity by starting with accessible values. Periodically revisit community norms and provide group feedback that encourages collaboration and community. Provide ongoing feedback that helps students maintain sustained effort and persistence during a task and encourage self-reflection and identification of personal goals.

UDL: Representation

- Present content using multiple modalities.
- Annotate displays with specific language, different colors, shading, arrows, labels, notes, diagrams, or drawings.
- Provide appropriate reading accommodations.
- Support use of vocabulary, mathematical notation, and symbols with charts, pictures, diagrams, and tables.
- Highlight connections between representations to make patterns and properties explicit.
- Present problems or contexts in multiple ways, using diagrams, drawings, pictures, media, tables, graphs, and other mathematical representations.
- Use translations, descriptions, movement, and images to support unfamiliar words or phrases.
- Activate or supply background knowledge to build connections to prior understandings and experiences.
- Provide access to blank or partially-completed outlines, graphic organizers, or representations, to emphasize key ideas and relationships.
- Maximize transfer and generalization by naming connections to previous examples, inviting students to identify important details or features to remember

Teachers can reduce barriers and leverage students' individual strengths by presenting content using multiple modalities and annotating displays with specific language, different colors, shading, arrows, labels, notes, diagrams, drawings, etc. Support the use of vocabulary, mathematical notation, and symbols with charts, pictures, diagrams, and tables, and use translations, descriptions, movement, and images to support unfamiliar words or phrases. Present problems or contexts in multiple ways, using diagrams, drawings, pictures, media, tables, graphs, and other mathematical representations, and highlight connections between different mathematical representations to make patterns and properties explicit. Activate or supply background knowledge to build connections to prior understandings and experiences and maximize transfer and generalization by naming connections to previous examples, inviting students to identify important details or features to remember. Provide reading accommodations as needed, as well as blank or partially-completed outlines, graphic organizers, or representations, to emphasize key ideas and relationships.