

# Teacher Handbook:

## Overview of the Core Knowledge Middle School Science Program



GRADES 6–8 Core Knowledge Science®



Core Knowledge®





# Teacher Handbook:

Overview of the Core Knowledge  
Middle School Science Program

Core Knowledge Science



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ISBN: 978-1-68380-833-6

# Teacher Handbook

## Middle School Science

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# About the Teacher Handbook

Core Knowledge Middle School Science is an enhanced republication of the OpenSciEd Middle School curriculum. The OpenSciEd Project is a revolutionary effort to implement the recommendations of the National Research Council in its 2012 *Framework for K–12 Science Education* (National Research Council, 2012), as embodied in the science standards of the more than 35 states that have used the NRC Framework and the Next Generation Science Standards (NGSS Lead States, 2013) to inform their standards-writing processes. The objective of the OpenSciEd Project is to create and disseminate instructional materials that implement the approach to science teaching and learning that has come to be known as *three-dimensional science learning* since the release of these documents.

To achieve this objective, OpenSciEd calls for teaching practices that have not been part of the repertoire of most science teachers historically. While the units are designed to provide teachers who are new to three-dimensional learning with enough support to implement the units successfully, this *Teacher Handbook* provides overviews of features of the units that are likely to be new to many teachers. Each chapter focuses on a different feature.

The *Handbook* is not designed to be read from front to back. We envision that teachers will read some chapters as an introduction to the OpenSciEd approach as they begin to plan for instruction and will choose to read others on an as-needed basis as they go through the planning process. Most important, the *Handbook* is designed to be a resource that teachers can refer back to at any time.

The *Handbook* is neither a comprehensive reference on the program nor a tutorial on how to implement the teaching practices. The developers believe that teachers learn new practices by doing—through the acts of planning, implementing, reflecting, and replanning. This *Handbook* is envisioned as one support for that learning-by-doing process, ideally in combination with other informational resources, peers, and experts.

## Unit Pacing

The unit pacing is based on one day of instruction occupying a 45- to 60-minute class period.

	Grade 6	Grade 7	Grade 8
Unit 1	Light and Matter 18 days	Chemical Reactions and Matter Transformation 25 days	Contact Forces 33 days
Unit 2	Thermal Energy 37 days	Energy in Chemical Reactions 20 days	Sound Waves 24 days
Unit 3	Weather, Climate, and Water Cycling 41 days	Metabolic Reactions 29 days	Forces at a Distance 30 days
Unit 4	Plate Tectonics and Rock Cycling 30 days	Matter Cycling and Photosynthesis 29 days	Earth in Space 32 days
Unit 5	Natural Hazards 20 days	Ecosystem Dynamics and Biodiversity 40 days	Genetics 28 days
Unit 6	Cells and Development 30 days	Natural Resources and Human Impact 39 days	Natural Selection and Common Ancestry 35 days

### Emphasized Performance Expectations

Physical Science
Earth and Space Science
Life Science

## A. The Instructional Approach

The units in this program are designed using a form of “science storyline” approach. The goal of a science storyline approach is to provide students with a coherent experience that is motivated by the students’ own desire to explain something they don’t understand or to solve a problem (Reiser, Novak, & McGill, 2017). The metaphor of a storyline captures the notion that learners should be motivated to work through the next step in a science unit just as they are motivated to see what happens next in an unfolding story.

A unit storyline is a logical sequence of lessons that are motivated by students’ questions. It is a science storyline because the questions arise from students’ interactions with phenomena. Unit storylines are designed to provide students with the goal of explaining a phenomenon and/or solving a problem. Each step is designed to enable students to make progress on their questions by using science and engineering practices to help them figure out a piece of a science idea. Each piece they figure out adds to the developing explanation, model, or designed solution. Each step may also generate new questions that add to students’ work in the storyline. As a stepwise process of questioning, investigating, and building understanding, a storyline provides a coherent path toward building a disciplinary core idea and crosscutting concepts, anchored in students’ own experiences and questions.

### Why use science storylines to organize units?

In traditional approaches to science teaching, units are sequenced based on how experts understand the relationships among concepts. This means that it typically requires an understanding of the concepts being taught to understand why a unit is sequenced the way it is. The result is that the sequence of activities may make sense to a teacher but doesn’t necessarily make sense to the students. For example, a teacher may understand how certain activities to learn about cells will help students understand important biological concepts, but students may only know that they are learning about cells because that’s the title of the current chapter in the textbook. Or a teacher may know how a particular chemistry experiment demonstrates something about conservation of matter, but the only reason their students may have for doing that experiment is that it is part of their assignment from the teacher.

In the science storyline approach, the sequence of activities is designed to make sense to students, lending coherence from the students’ perspectives. When a storyline is coherent from the student perspective, a visitor to the classroom on any given day should be able to walk over to a group of students and receive an answer that describes a question they are trying to figure out or a problem they are trying to solve.

There are four key considerations in the instructional approach:

- phenomena
- disciplinary Core Ideas
- science and engineering practices
- crosscutting concepts

The disciplinary core ideas, science and engineering practices, and crosscutting concepts reflect the *Framework for K–12 Science Education* and the performance expectations embodied by the Next Generation Science Standards and the standards of the more than 35 states that have used these documents to inform their state science standards.

### What is the role of phenomena?

Interesting phenomena are key to the storyline approach. Ultimately, every storyline is a journey to figuring out a phenomenon that defies easy explanation. It might be a surprising or puzzling phenomenon, something that violates the rules of the world that students have come to accept, such as an object that levitates. It might be a phenomenon students need to understand to address a problem, such as predicting and preparing for a violent storm. It might be a phenomenon that they want to know how to control, such as soil erosion on a farm. Or it might be an everyday phenomenon that mystifies students when they stop to think about it, like why droplets of water spontaneously appear on the outside of a glass of cold water.

Each unit phenomenon is carefully selected to anchor a storyline and to motivate the development of target disciplinary core ideas, crosscutting concepts, and science and engineering practices. These **anchoring phenomena** are used to draw students into the storyline by presenting the natural challenge of explaining something or solving a problem. Other phenomena may be introduced at key points in a storyline to maintain interest or push students to delve more deeply.

### What is the role of the disciplinary core ideas?

Students use disciplinary core ideas (DCIs) to make sense of how and why phenomena occur. These units are designed to help students draw on DCIs developed in the prior grade bands (K–5) and in prior units and to extend these ideas piece by piece as the unit progresses. Within units, lessons call out which elements of the DCIs are targeted and identify new aspects of these ideas that students begin to develop in the lesson. The unit overview and teacher background section for each unit explain the progression by which DCIs are incrementally developed and extended through the unit. The Scope and Sequence provides a pathway through which students can coherently build the target DCIs across three years of middle school, drawing on and revising ideas built in prior units.

### What is the role of the science and engineering practices?

In these units, science and engineering practices (SEPs) provide the avenue by which students develop new ideas and make new discoveries throughout the storyline. They use questioning to articulate what they need to figure out. They investigate to generate new ideas about why things work the way they do or to test their conjectures. They construct models and explanations to organize their ideas and share them with others. Science and engineering practices guide the work with phenomena and problems so that students can develop, test, and refine science ideas. Modeling and argumentation are particularly important practices in the early units and have additional supports available. See Section E of this handbook for more discussion on Science and Engineering Practices, and in particular modeling and argumentation.

### What is the role of the crosscutting concepts?

In these units, the crosscutting concepts (CCCs) are used to support student sensemaking in three general ways:

- By providing a scaffold to ask productive and investigative questions
- As a set of principles and heuristics to guide model building and explanation
- As a way to frame the sequence of students' experiences of related phenomena in ways that engage students in analogical reasoning

The CCCs are developed and used strategically to help students make connections within and across units and intentionally transition from highly scaffolded experiences with CCCs applied to curated phenomena (e.g., applying a rubric that highlights CCCs to students' models of a phenomenon) to limited scaffolding with uncurated phenomena (e.g., students applying ideas of matter and energy to a related phenomenon at the end of a unit).

In summary, each unit is anchored in a phenomenon or set of phenomena and strategically integrates the DCIs, SEPs, and CCCs to create a storyline path in which students and teachers, as a learning community, work together to manage the trajectory of their knowledge building. The class as a whole incrementally develops ideas over time, motivated by questions about phenomena in the world. Each step is an attempt to address a question or a gap in the class's current explanatory model, developing, using, and extending parts of the DCIs, SEPs, and CCCs as needed. The storyline approach supports students' agency in sensemaking: *we figure out the science ideas, and we put those ideas together over time.*

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*Portions of Section A were adapted from tools and processes developed by NextGen Science Storylines at Northwestern University and from the Next Generation Science Exemplar System Project (NGSX) at Clark University and Tidemark Institute. The work of NextGen Science Storylines was funded by support from the Gordon and Betty Moore Foundation, the James S. McDonnell Foundation, and the Carnegie Corporation of NY to Northwestern University; from the William and Flora Hewlett Foundation to the University of Colorado Boulder; and from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.*

## Summary of Instructional Elements

Element	Description
<p><b>Phenomena Based</b> Centered on figuring out phenomena or solving problems</p>	<ul style="list-style-type: none"> <li>• Students' work is anchored in meaningful phenomena or problems that motivate building ideas over time.</li> <li>• Anchoring phenomena and problems are complex, relevant, and returned to as we figure out more.</li> <li>• Students investigate related phenomena to figure out pieces of the explanation.</li> <li>• Assessments ask students to make sense of specific and compelling phenomena using their understandings built during the unit.</li> </ul>
<p><b>Coherent for Students</b> Driven by students' questions and ideas</p>	<ul style="list-style-type: none"> <li>• Students' prior ideas and understandings are elicited, valued, and built upon.</li> <li>• Students and teachers work together to figure out where to go next and what evidence is needed to answer their questions.</li> <li>• Students understand what they are doing and how it will help them answer questions about a larger phenomenon or solve a problem.</li> <li>• Students engage in science and engineering practices in meaningful ways in order to make progress on their questions.</li> </ul>
<p><b>Driven by Evidence</b> Incremental building and revision of ideas based on evidence</p>	<ul style="list-style-type: none"> <li>• Students' ideas and questions determine what evidence to collect.</li> <li>• Students seek and use evidence to figure something out as they build and revise their explanations, models, and arguments.</li> <li>• Investigations provide evidence to build new science ideas instead of confirming pre-taught ideas.</li> <li>• Evidence can be used to problematize our current thinking and help us think about where to go next.</li> </ul>
<p><b>Collaborative</b> <i>We figure out ideas together</i></p>	<ul style="list-style-type: none"> <li>• Students have opportunities to use, build upon, and critique others' ideas.</li> <li>• Students use evidence to support ideas, ask for evidence from others, and suggest ways to get additional evidence.</li> <li>• Students have several opportunities to give and get feedback</li> <li>• The culture of the classroom supports risk-taking and changing our minds.</li> </ul>
<p><b>Equitable</b> Requires a classroom culture that values all ideas</p>	<ul style="list-style-type: none"> <li>• Students have multiple opportunities to make sense individually and through small- and whole-group discussions.</li> <li>• The class community values the diversity of resources students bring to science class, including language, gestures, metaphors, and various modes of expression.</li> <li>• Norms are established and revisited to support equitable sensemaking.</li> <li>• Teachers integrate a variety of assessment activities to elicit, interpret, and provide feedback to build from students' diverse ideas and experiences.</li> <li>• Students understand how and why what they are learning is relevant to their own lives and their communities.</li> </ul>

## B. Organization of Units

The science units are organized into collections of lessons called *lesson sets*. Each lesson set advances the storyline by investigating one aspect of the anchoring phenomenon. Each lesson set in an unit is an inquiry cycle in which students pose questions about some aspect of a phenomenon, explore the phenomenon through scientific investigations, and then work to make sense of their observations. At the end of a lesson set, students put their ideas together to express a more complete or sophisticated understanding of the phenomenon than they entered the lesson set with.

A lesson set is made up of individual lessons, each of which has several parts, or *activities*, that work together to help students make sense of some phenomenon or problem. Lessons range in length from one class period to several. To help you understand the organization of the units, here is a generic structure of an individual unit\*:

Unit: Unit Driving Question (i.e., the unit title)

- Lesson Set 1
  - Lesson 1: Anchoring Phenomenon and Driving Question Board
    - Activity 1: Name of Activity
    - Activity 2: Name of Activity
  - Lesson 2: Investigation
  - Lesson 3: Investigation
  - Lesson #: Putting Pieces Together and Problematizing
- Lesson Set 2
  - Lesson #: Investigation or Reanchor with Another Phenomenon

\*See Sections A and C for more information about the instructional model.

Each unit has several components. For teachers, there is a **Teacher Guide** for each unit that describes the lesson procedures and instructional strategies, including key ideas for teachers to emphasize in each lesson. These guides are comprehensive, including example questions to ask at particular points in the lesson and example student responses. These guides are intended to be used not as a script but rather as suggestions for how to implement the lessons, which teachers can start with when planning instruction for their specific settings and students. Teachers are also provided with **additional lesson resources**, such as lab instructions, keys, and rubrics, as appropriate for the lesson, and each lesson has **presentation slides** that teachers can project and use as they move through each lesson.

Each unit also comes with a **Student Procedure Guide**, which provides lesson procedures, references, and very limited readings. Students can use the Student Procedure Guide to consult various full-color versions of references or readings during lessons or to recreate any missed investigations in the case of an absence. In addition to this Student Procedure Guide, there are **Student Work Pages** designed for situations where students need to draw or write on an image or graphic organizer. These pages from the consumable booklet are intended for students to write on and keep in their notebooks or to turn in for assessment purposes. Students also have access to **interactive resources**, such as simulations, to interact with as they are figuring out science ideas. The **Science Literacy Student Reader** is a Core Knowledge addition to the program, providing weekly collections of short reading selections related to the science topics students are investigating in any given week. Finally, all students need to have a **science notebook** to use for written work throughout the unit.

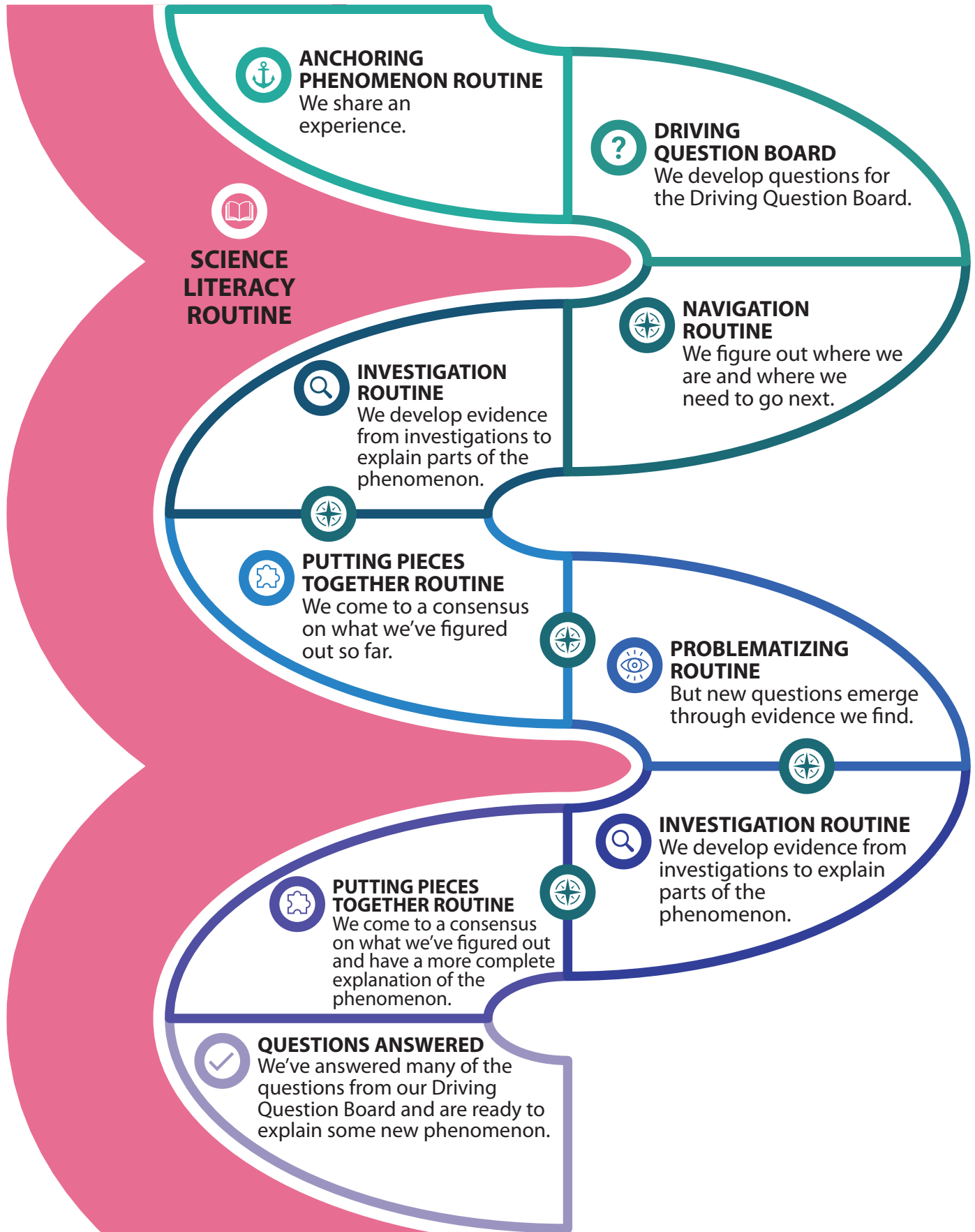
## C. Instructional Routines

To help teachers and students advance through a unit storyline, the program’s instructional approach implements routines—activities that play specific roles in advancing the storyline with structures to help students achieve the objectives of those activities.

Units use five routines drawn from the work of the NextGen Science Storylines Project (Reiser, & Novak, McGill, 2017) and one routine introduced by Core Knowledge:

Routine	Purpose
Anchoring Phenomenon routine	Develop curiosity to drive learning throughout the unit based on a common experience of a phenomenon and connections to any related phenomena students have experienced.
Navigation routine	Establish and reinforce the connections among what we have previously done in a unit, what we are about to do, what we will do in the future, and what our driving purpose is in the context of the unit.
Investigation routine	Use scientific practices to investigate and make sense of a phenomenon.
Putting Pieces Together routine	Take the pieces of ideas we have developed across multiple lessons and figure out how they can be connected together to account for the phenomenon we have been working on.
Problematizing routine	Evaluate the adequacy of our scientific ideas to explain a phenomenon in order to identify what we still need to understand.
Science Literacy routine	Read, evaluate, and write about science topics to build and reinforce background knowledge and critical thinking ability.

How and where the routines are found will vary somewhat across the units, but these routines typically follow a pattern as students kick off a unit of study, investigate different questions they have, put the pieces together from those investigations, and then problematize the next set of questions to investigate. Each unit will have slight variations in what happens within a particular routine, based on the anchoring phenomenon and the focal SEPs and CCCs, but the purpose and general approach of the routine are consistent across all units. The Instructional Model on the following page provides a general path through a unit using the routines. The Core Knowledge Foundation supplements the five classroom routines with the addition of the Science Literacy routine.



## Anchoring Phenomenon Routine

### ***Kicking Off a Unit with an Experience to Motivate Investigation***

#### **What is it, and what is its purpose?**

The Anchoring Phenomenon routine is used to kick off a unit of study and drive student motivation throughout the unit. The purpose of the Anchoring Phenomenon routine is to build a shared mission for a learning community to motivate students in figuring out phenomena or solving design problems. More specifically, the Anchoring Phenomenon routine serves to ground student learning in a common experience and then uses that experience to elicit and feed student curiosity, which will drive learning throughout the unit. The Anchoring Phenomenon routine also serves as a critical place to capture students' initial ideas as a pre-assessment opportunity.

The Anchoring Phenomenon routine

- creates an opportunity for students to voice their initial ideas about the phenomenon;
- identifies the areas of agreement and disagreement in students' ideas about the mechanisms behind one or more aspects of the phenomenon;
- exposes to the teacher what students do and do not know about these mechanisms; and
- elicits questions that the students want to investigate and answer throughout the unit, which the teacher will be able to use to motivate students and connect the lessons in the unit.

#### **When is it conducted?**

The Anchoring Phenomenon routine is introduced at the beginning of a unit.

#### **How do students typically represent their thinking as part of the routine?**

The Anchoring Phenomenon routine pushes students to represent their initial thinking by writing or drawing and sharing their own initial models, explanations, or design solutions. These might be represented in their science notebooks. In the Anchoring Phenomenon routine, students also create a shared classroom representation of an initial class consensus model, a Driving Question Board, and ideas for potential investigations (all discussed in this handbook).

#### **Typical Elements of the Anchoring Phenomenon Routine**

##### *Element 1: Explore the Anchoring Phenomenon*

Every unit starts with a puzzling phenomenon that students experience and explore in some way. In this initial exploration, the question the class focuses on is, "What do we notice?" For example, students might make observations, look for patterns, or create a timeline of events that occurred. The purpose of this element is for students to recognize the interesting events going on and to publicly, as a learning community, acknowledge aspects of the phenomenon that require explanation.

##### *Element 2: Attempt to Make Sense*

In the "making sense" element, students try to come up with an explanation, model, or some other reasoning to explain why or how the phenomenon under investigation is happening. The point of this element is for students to voice their initial ideas about the phenomenon, no matter how inaccurate or far-fetched they may be. The purpose is to lay a foundation for the investigations they will conduct throughout the unit that will lead them to a scientific understanding. By trying to make sense of the phenomenon themselves, students generate ideas that lead to questions and theories that they will want to investigate.

It's important that each student tries individually to make sense of the phenomenon and then goes public with their ideas. Diversity in our sensemaking ideas is very productive! It helps create the sense that we are not all on the same page and that there are things here that beg to be figured out. The role of the teacher in this part of the routine is twofold: (1) to help students get their thinking down on the page, regardless of whether it's right or wrong, and (2) to push students to come up with a mechanistic explanation of what's going on. Press students to go deeper if they think they know the answer. More likely than not, even students who use correct vocabulary to explain what they think is going on cannot really tell you what those words mean in a mechanistic way.

An example sequence of this element follows:

- Individual sensemaking (e.g., developing a model in their science notebooks)
- Intermediate sensemaking (e.g., considering how their own model compares to another's, which can be done with partners, small groups, or a gallery walk)
- Class sensemaking conversation and initial consensus model

#### *Element 3: Identify Related Phenomena*

The goal of each unit isn't just to solve a single mystery about one phenomenon. The goal is to build up disciplinary core ideas and crosscutting concepts that can be applied to a range of events in our world. The purpose of having students identify related phenomena is to broaden the scope of what the class is really interested in figuring out and for students to have a personal connection with and investment in the events being explored in class.

An example sequence of this element follows:

- Students write in their notebooks about related phenomena from their personal experience.
- Students have an opportunity to share their experience with classmates.
- The class may create a public representation of students' ideas to organize students' sharing of related phenomena and get students to attend to certain features (patterns) across related phenomena (if it makes sense to do so).

#### *Element 4: Pose Questions to Resolve and Discuss Next Steps*

In the fourth element, the class uses a Driving Question Board (DQB) to create a joint list of questions and action items to help them understand the anchoring phenomenon. What's unique about three-dimensional learning is the opportunity for students to be involved in the thought process and decision-making about what the class should be figuring out and how. It is important for each student to participate in generating a question to be explored and for those questions to be made public so that the class as a whole retains ownership of those questions. Similarly, students should be involved in thinking of ways to go about answering one or more of the questions from the class. The point of doing this is for students to identify actionable ways to figure out answers to their questions. For example, the class may think a good way to follow up on one of the questions is to look up what experts have to say or to gather secondhand data. The goal isn't to come up with the perfect question or solution. Questions and next steps will be revised, revisited, and checked off as the unit progresses.

An example sequence of this element follows:

- The teacher asks, "What do we want to know next?"
  - Students write individual questions.
  - Students share questions aloud.
  - The class organizes the questions on the DQB.
- The teacher asks, "What do we want to do next?"
  - Students brainstorm investigations that could help them figure out their questions and why the investigations might help.
  - The class posts their ideas near the DQB.

## **Navigation Routine**

### ***Motivating the Next Step in an Investigation***

#### **What is it, and what is its purpose?**

The Navigation routine enables students to experience the unit as a coherent storyline in which each activity has a purpose and is connected to what has gone before and what is coming. It also provides a valuable opportunity for students to reflect on their learning over time.

## When is it conducted?

The Navigation routine is conducted throughout the unit at transition points.

## How do students typically represent their thinking as part of the routine?

The Navigation routine is all about linking learning across lessons and activities. Students might represent their thinking in the following ways:

- Revisiting their initial ideas and focus questions in their science notebooks
- Revisiting their individual models in their notebooks to add to or revise their thinking
- Recording a “consensus” model using a Progress Tracker in their notebooks and publicly in the classroom
- Returning to the Driving Question Board to answer questions, add new questions, or refine their questions

## Typical Elements of the Navigation Routine

*Element 1: Look Back: How did we get here?*

- **Routine at the start of a new lesson:** At the beginning of each lesson, the class asks, “What brought us to this point?” The learning community needs to look back and remind themselves: “Where are we in our mission? What have we accomplished? What’s the main thing we need to work on now? What was our question?” Oftentimes, instructional materials prompt teachers or students to recall where the class left off. Although the teacher may have to start the conversation, the work of reflecting should be done by the students as much as possible.

*Element 2: Take Stock: Where are we now?*

There are many time points during a lesson when the class might be able to assess where they currently are in the lesson to strengthen connections between activities and the storyline. These time points include the following:

- **Routine in the middle of a lesson, during or between activities:** Throughout the lesson, students should continue to engage in making connections between what they are doing, where they have been, and where they are going. It is easy to lose track of the larger storyline in the midst of an interesting hands-on activity. The teacher engages students in thinking about what they are doing and what it has to do with the bigger questions they are trying to answer, both in between activities and during the activities themselves.
- **Routine at the end of a day when a lesson isn’t complete:** Often, class time ends before a lesson is complete. At this point, students and the teacher should take stock of where they are in the learning—what they accomplished in that class that helps them answer the driving question and where they will go during the next class. This could be as simple as students (and/or the teacher) making a summary statement at the end of class, but it should be a whole-class statement with some individual student thinking time.
- **Routine to pick up the next day to finish an incomplete lesson:** When a lesson picks back up at the start of a new class period, students need the opportunity to reflect on where they left off in the previous class period, what they were trying to figure out, and where they need to pick back up in their work.

*Element 3: Look Forward: Where are we going?*

- **Routine at the end of a lesson:** Each lesson ends with another reflection or a look back, in which the class asks: “Where are we in our mission? What have we accomplished in this lesson? What’s the main thing we need to work on now? What was our question?” After the class has a chance to think about these kinds of questions, they ask, “Where do we need to go next?” When the class looks forward, the students, together with their teacher, talk through the next question or direction to pursue. Involving students in this work is critical for helping them develop into problem-solvers and to position students as partners in figuring out how the world works.

Example strategies in lessons for the Navigation routine include the following:

- Review data from previous class exit tickets.
- Brainstorm related experiences connected to what the class will do that day.
- Use a home learning assignment from the previous class (focused on noticings or wonderings) and home observations of some phenomenon, to pull in new ideas the class will need that day.
- At the start of class, meet at the DQB to identify where the class left off the previous class period.
- Have students use the Progress Tracker individually, with a partner, or in small groups to track progress toward answering a question.

- Give one minute of silent thinking and writing time to jot down what the class figured out previously, and have students share with a partner and/or the whole class.
- Check in on classroom norms to prepare for group work or consensus discussions that will occur or to review those that did occur that day.

## Investigation Routine

### **Using Practices to Figure Out Science Ideas**

#### **What is it, and what is its purpose?**

The purpose of the Investigation routine is to use questions around a phenomenon to lead the class to engage in science practices to make sense of the phenomenon and then develop the science ideas as part of the explanation. This is the basic structure of the work of three-dimensional learning.

#### **When is it conducted?**

The Investigation routine is conducted throughout the unit, whenever students identify gaps in their understanding of the anchoring phenomenon.

#### **How do students typically represent their thinking as part of the routine?**

Students represent their thinking during Investigation routines in many different ways, including these:

- Developing a plan of action
- Recording observations and measurements
- Organizing evidence
- Articulating new ideas and comparing them to current models
- Revising models
- Revising the Driving Question Board

### **Typical Elements of the Investigation Routine**

The Investigation routine is the primary routine that students use when they are in the middle of an activity and trying to figure out something or design solutions to a problem. This routine has three elements to help set up an activity, do the activity, and follow up on the activity.

#### *Element 1: Create a Plan of Action*

In the first element, the class works together to articulate a plan of action for investigating a particular question or to discuss why certain things might be measured or attended to during an investigation. This element helps the class figure out their question. Examples of questions that guide the plan include the following:

- How do we plan an investigation?
- What variables do we need to measure and control?
- What do we need to focus on in our observations?
- How are we going to record our observations?
- What do different components represent in the real world?
- What do we think might happen?

#### *Element 2: Do the Work with Science and Engineering Practices*

Students use science and engineering practices such as carrying out investigations, analyzing data, modeling, and argumentation to make sense of puzzling phenomena, answer questions, and make progress on their explanations. The bulk of the class's time and energy is spent in this element. Students should be doing the heavy lifting of figuring out. For example, if you ask students what they are doing at any moment during an activity, they should identify a phenomenon they are trying to figure out or a question they need to answer. Examples of practices include the following:

- Collecting data through hands-on experiments or computer simulations
- Analyzing graphs or data
- Examining and critiquing evidence

- Observing and manipulating physical models to explain phenomena
- Comparing how well competing models can fit and explain data

*Element 3: Make Sense: What did we figure out?*

At each step, students assemble another piece of the puzzle through the process of summarizing and synthesizing new information about a phenomenon. It might be a piece of a disciplinary core idea, such as the idea that a vibrating object can make sound. They may also be extending their ideas of crosscutting concepts such as matter and energy. Notice that students don't learn about the science ideas first and then engage in practices to use those science ideas to explain a phenomenon, but rather the reverse. Examples include the following:

- Revising or refining a model
- Participating in a consensus discussion (e.g., expressing agreement or disagreement with the ideas or findings of others)
- Revisiting the Driving Question Board (e.g., students ask, "How did it help us answer X question?"; this may overlap with the Navigation routine)

## Putting Pieces Together Routine

### **Using the Science Ideas We've Built So Far**

#### **What is it, and what is its purpose?**

In the Putting Pieces Together routine, students take the pieces of ideas they have developed across multiple lessons and figure out how they can be connected to account for the phenomenon the class is working on. This routine serves to help students take stock of their learning and engage with the class to develop a consensus representation, explanation, or model to account for the target phenomenon (the phenomenon anchoring the unit or learning set).

#### **When is it conducted?**

The Putting Pieces Together routine is conducted at strategic moments when students have synthesized evidence from a range of situations to construct an important component of the explanatory model. This is often at the end of a lesson set or at the end of the unit.

#### **How do students typically represent their thinking as part of the routine?**

Students typically represent their thinking through the following:

- A "gotta-have-it" checklist
- A class consensus model

### **Typical Elements of the Putting Pieces Together Routine**

*Element 1: Take Stock*

The first element focuses on taking stock of the main science ideas the class has figured out so far. This could take different forms. First, students need time to reflect on what it is that they are trying to figure out. Then students need to determine which of the information they've gathered so far might be helpful for them. Students might highlight in their science notebooks the important discoveries they made or revisit their Model Trackers. Or they might refer back to a series of posters of scientific principles that the class has been adding to, lesson by lesson, to keep track of their discoveries over time. The purpose of this element is to get all the pieces of the puzzle out on the table.

*Element 2: Put Pieces Together*

The second element of the routine involves three parts:

1. Students attempt to put ideas in the gotta-have-it checklist to explain the phenomenon or design a solution, working individually first so that all students are given the opportunity to synthesize the evidence and formulate their ideas. This part is important so that all students are prepared to defend their ideas, evaluate one another's ideas, and consider their ideas in the context of others' ideas.
2. Students share and revise their ideas with a partner or in small groups to surface areas they agree they want to see represented in the class consensus model. This step is important to ensure that all students have the opportunity to articulate their ideas to someone else to help deepen their understanding and begin the process of considering their ideas in the context of others' ideas. This also creates a safer space for students

who might be less willing to participate in a larger setting. In addition, this helps the partners or small groups identify ideas or features they want to bring to the class consensus model.

3. The class has a *consensus-building discussion* in which students draw on their work to share and evaluate alternate models or explanations and to contribute to the gotta-have-it checklist to explain a phenomenon or design a solution. During this process, the class develops a public representation of the ideas as they are putting them together, such as a diagrammatic model, a table showing commonalities across a series of cases, or a written explanation. The result is a revised class consensus model.

#### *Element 3: Revisit the Driving Question Board*

Depending on when this routine happens in the unit, students may consider what puzzle pieces they have just put together, take stock of what they have figured out, and then revisit the questions on the Driving Question Board. This move can motivate them to identify what further questions need to be investigated as the class moves into the next lesson set.

#### *Element 4: Apply This to Another Phenomenon (Optional)*

Sometimes the class is ready to go further, and there may be a fourth element of this routine. After the class comes to a consensus on a public representation of how the pieces fit together and students feel confident about the model, they may attempt to explain new phenomena or solve a new problem. They may learn additional ideas that might be useful for explaining the phenomenon and consider the generalizability of their ideas.

## **Problematizing Routine**

### **Motivating Learning through Each Part of a Unit**

#### **What is it, and what is its purpose?**

The purpose of the Problematizing routine is to reveal a potential problem with the current model, explanation, or design solution in order to motivate students to extend or revise their models. The teacher seeds, cultivates, and capitalizes on an emerging disagreement that reveals the potential problem and gets students to focus on an important question that could extend their models.

#### **When is it conducted?**

The Problematizing routine is often conducted after a Putting Pieces Together routine or at strategic points where students need to recognize that there is more to figure out.

#### **Typical Elements of the Problematizing Routine**

The Problematizing routine has a great deal in common with the Anchoring Phenomenon routine. Both routines are about helping students see that there are aspects of a phenomenon that they are unable to explain. Whereas the Anchoring Phenomenon routine presents students with the puzzling aspects of a phenomenon for the first time, the Problematizing routine typically focuses on a phenomenon that students are already familiar with and presents them with aspects of the phenomenon that they have not yet figured out how to explain. Therefore, the first element that appears in the routine typically is different from the first element in the Anchoring Phenomenon routine, but the elements that follow are typically the same as those in the Anchoring Phenomenon routine.

#### *Element 1: Identify Aspects of the Phenomenon That the Consensus Model Can't Explain*

The student or teacher presents the learning community with an aspect of the anchoring phenomenon or a new, related phenomenon that is a problem for the students' current consensus model to explain. The role of the teacher in this element is to draw attention to the problem and press the class to determine whether a particular key science idea (or set of ideas) they developed could be pushed beyond what they had considered so far.

#### *Element 2: Understand the Limits of the Model and Consider Ways to Revise It*

See the "Element 2: Attempt to Make Sense" step of the Anchoring Phenomenon routine.

#### *Element 3: Pose Questions to Resolve and Discuss Next Steps*

See the "Element 4: Pose Questions to Resolve and Discuss Next Steps" step of the Anchoring Phenomenon routine.

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*Portions of Section C were adapted from tools and processes developed by NextGen Science Storylines at Northwestern University and from the Next Generation Science Exemplar System Project (NGSX) at Clark University and Tidemark Institute. The section on anchoring phenomena also draws on the work of the Investigating and Questioning Our World through Science and Technology Project at the University of Michigan, Northwestern University, and Michigan State University.*

# Science Literacy

“To be culturally literate is to possess the basic information needed to thrive in the modern world.”

— E.D. Hirsch Jr. in the preface to *Cultural Literacy: What Every American Needs to Know*

Core Knowledge curricula are grounded in the notion of cultural literacy—that shared knowledge is the medium through which individuals can associate and effectively form and keep societies. Accessing shared background knowledge opens doors to productive and responsible citizenship. The fundamental meaning of literacy is the ability to derive meaning from texts and visual imagery and convey meaning through text and visual content knowledge. In the broadest sense, literacy is empowerment.

Science literacy is, at the least, one pillar of cultural literacy, and arguably the very foundation of it. Core Knowledge regards science literacy as the ability to read, visualize, speak, hear, comprehend, and evaluate content about scientific topics and then demonstrate understanding in various ways.

It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of poor information on social media. Misinformation, misinterpretation, and misrepresentation spread like brush fire. Detection and construction of well-reasoned explanations are important not just in science but also in everyday life. Using claims and evidence in reasoning is a way that thoughtful people think about things and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

## Core Knowledge Science Literacy in Practice

Core Knowledge Science Literacy is designed to be used in conjunction with the classroom investigations in the Middle School Science Program. The eighteen units of phenomenon-based investigation were designed to fully meet the three-dimensional and equity-focused aspirations of the Next Generation Science Standards. Within the unit investigations, students write in their science notebooks in some fashion almost daily, and that is certainly literacy support. There is great emphasis on the speaking and listening communication threads of Common Core literacy standards in units. However, the classroom lessons are deliberately light on having students access unit content through text. NGSS emphasis is on students investigating phenomena along a storyline, so students’ interaction with text is minimal, and all reading is in service to the unit’s storyline. Each unit is cohesive, and working with text isn’t the central work of the unit. However, in their lives after graduating from high school, most students will not become scientists. They will no longer be participating routinely in supported inquiry to figure out how phenomena work. They will, however, be reading text and seeing visual information about science and scientific claims, day in and day out. The ability to learn science through reading and interpreting visual information is a skill unto itself and critical in tandem with investigative learning.

Core Knowledge Science Literacy adds a sixth routine in which students read, evaluate, and write about science topics to build and reinforce background knowledge and critical thinking ability.

## Science Literacy Routine

*Reading, Evaluating, and Writing About Related Science Topics*

### What is it, and what is its purpose?

The Science Literacy routine is used to exercise students’ ability to interact with text and visual information about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing of the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

## When is it conducted?

The **Core Knowledge Science Literacy Student Reader** includes one reading selection per week for every week of the unit. A week's reading selection relates to the lessons completed in the *previous* week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

## How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single thoughtfully reasoned and well-constructed paragraph.

Exercise Pages supplied in the Teacher Guide provide the following:

- Close reading support
- Scaffolding for written responses
- Rubrics for evaluation

You may elect to have students accumulate their writing products into a portfolio for the unit or for all units across the entire school year.

## Typical Elements of the Science Literacy Routine

### *Element 1: Read*

At the start of the week, the teacher introduces the reading selection and previews expectations for the writing exercise.

A reading selection will typically take students less than half an hour to complete independently. The selection itself will be composed of multiple parts of varying styles or genres. For example, parts of reading selections may be presented as the following:

- Excerpts from popular articles from topical or entertainment print magazines
- Excerpts from scholarly articles from peer-reviewed academic or professional journals
- News reports from established journalism sources
- News reports from self-published or cottage sources or websites
- Newsletters or special interest publications
- Social media posts, which may include memes, personal opinions, and rumors
- Advertisements, which may include product claims
- Interviews, as summary articles or transcripts
- Expository passages, such as textbook excerpts
- Creative media formats, such as infographics or graphic novel excerpts
- Summaries or reviews of entertainment media, including movies, TV, video games, and music

An example sequence for this element follows:

- Guide students on a flip-through-the-pages pre-reading scan of the pages of the reading selection.
- Invite students to share their anticipatory impressions about the reading selection.
- Tie clues from the headers, images, and other evident features in the reading preview to key points from the previous week's lesson investigations.
- Distribute the Exercise Page.
- Preview the elements of the Exercise Page. Distinguish the parts dedicated to reading guidance from the instructions for the written assignment. Call attention to the rubric or scoring guidance against which students will be evaluated.

### Element 2: Evaluate

Each week's exercise asks students to thoroughly read the selection with specific, evaluative objectives in mind. By the middle of the week, students have read the week's selection with close reading guidance provided on the Exercise Page.

Students are asked to classify the purpose of text as one of the following:

- A description or definition or something
- An explanation of how something works or why it is the way it is
- A procedure, instructions, or steps in an event or process
- An argument of a point or attempt to persuade

Evaluative questions such as these guide thoughtful reading:

- What's the science here? (What parts are data, evidence, and conclusions?)
- What (and who) is the source? (What can I tell about the source's credibility? What can I tell about the source's motives?)
- Is the writer trying to persuade me? (Is there anything debatable or controversial about the message? Why does it matter?)

Students are now working on their written exercise in response to the reading. The teacher conducts a status check to answer questions students may have about the reading selection or the writing exercise.

An example sequence for this element follows:

- Administer a very basic minute quiz to confirm that students have undertaken the reading.
- Ask students to share a quick, concise verbal summary describing the format and subject of the reading selection.
- Ask students to briefly express in their own words how they are being asked to evaluate the reading selection.
- Ask students to briefly describe in their own words the expected exercise deliverable.
- Review in detail the rubric or scoring guidance for the exercise provided on the Exercise Page. Solicit student questions and clarify expectations.

### Element 3: Write

Students organize and reveal their thinking about text by producing text of their own. Emphasis is on thought process and precision, not volume. In fact, the heftiest artifact students are ever asked to produce in any given week is a single paragraph.

Like the reading selections, students' writing (and drawing, graphing, etc.) products take a variety of forms. Students are tasked with preparing a specific type of written learning artifact each week. The form of the students' deliverable is paired with the reading selection, and the writing process for the form is stepped out on the Exercise Page. In some cases, the Exercise Page provides a shell for guided note-taking; in other cases, the organization and writing cues are more open-ended. In all cases, a rubric or scoring guidance for the week's particular form is included up front, as a gotta-have-it checklist for student to understand before they respond to the exercise.

The complexity of the products increases from week to week, with the final product for the unit being a single thoughtfully reasoned and well-constructed paragraph. For example, in a unit with six weeks of reading selections, students might generate a portfolio of writing forms such as these:

Week 1	A Venn diagram classifying similarities and differences
Week 2	A table of causes and effects or pros and cons
Week 3	Cartoon frames contrasting a fact-versus-opinion argument or objective versus subjective words and phrases
Week 4	A storyboard depicting a sequence of events
Week 5	An outline summarizing key points of provided text or showing the relationship between a claim and its supporting evidence
Week 6	A paragraph making a claim, supported by evidence and reasoning

#### *Element 4: Share*

At the end of the week, students deliver their written products. The class comes together for a critical but brief discussion about the reading selection itself and for reflection on the thinking they needed to undertake in their completion of the writing exercise. The Teacher Guide provides detailed support for facilitation.

An example sequence for this element follows:

- Revisit classroom community norms for consensus discussions.
- Facilitate discussion about the reading selection. Invite students to
  - describe the author and the author's purpose;
  - characterize the knowable degree of credibility and/or bias of the author;
  - restate facts in the text that relate specifically to students' unit investigations;
  - identify claims in the text;
  - differentiate substantiated claims from opinions in the text;
  - elaborate on the evidence that supports a claim or lack thereof; and
  - express agreement or disagreement with a claim and provide reasoning.
- Invite reflection on the writing exercise. Ask students
  - what challenged them about completing the writing exercise; and
  - what they took away from the text as a result of the writing exercise that they might not have otherwise noticed.
- Collect students' writing products. Evaluate according the rubric or scoring guidance provided at the initiation of the routine. Provide timely and substantive feedback to students with the return of their writing product.
- Optionally, have students add their writing product to their portfolios.

#### **Developing and Using Science and Engineering Practices within the Science Literacy Routine**

Purposeful reading provides repeat, reinforcing practice contributing to these science and engineering practices (SEPs):

- Asking questions
- Analyzing and interpreting data
- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

#### **Developing and Using Crosscutting Concepts within the Science Literacy Routine**

Student Reader selections are composed to bring the CCCs into specific focus. Text topics relate to DCI content, and they contain abundant analogous examples. Cues embedded in the close reading and discussion guidance for every selection tease out the presence of CCCs.

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

## Assessment

The Teacher Guide provides multiple tools for teacher assessment and student self-assessment at point of use.

- **Formative assessment:** A midweek checkpoint discussion determines students' understanding of expectations and whether or not they are on track with the exercise. Questions specific to each reading selection are provided for low-stakes minute quizzes to make students accountable for completing the reading by midweek.

Example questions:

- Do the forms in this week's reading selection look like advertisements, graphics, interviews, or social media posts?
- Is this week's reading selection about sounds made by guitars, trains, or whales?
- **Rubrics and scoring guidance:** Each writing exercise includes a gotta-have-it list that clearly specifies for students the important criteria for their evaluation of the reading and their writing response. In some cases, such as for full paragraphs, the criteria are presented in a structured rubric that includes rigorous expectations for grammar and mechanics. In other cases, such as for graphic organizers, the criteria are looser and focused only on the organization of ideas. The complexity of the assessment instrument matches the complexity of the assignment.

Here is a generic example of a paragraph evaluation rubric:

Element	1	2	3	Feedback
Topic sentence	Missing, or doesn't prepare the reader for what is to come in the paragraph	Unclear, or misguides the reader about what the coming details will support	Gains the reader's interest and clearly sets expectation about the purpose of the text that follows	
Supporting sentences (details)	Incomplete sentences, or details irrelevant to the paragraph topic	Complete sentences, but too few, lacking in support, or unclear relationship with the topic sentence	At least six complete sentences, encompassing three major points from the reading that support the topic sentence	
Organization and transitions	Statements with little clear relationship to the topic sentence or each other	Key supporting details present, but lacking or with choppy transitions	Ideas in an order that helps the topic make increasingly more sense	
Conclusion	Ends abruptly or with statement unrelated to the topic sentence	Restates the topic sentence, but does not make a claim	Wraps up the paragraph with a reasoned claim and refers back to the topic sentence	
Grammar and mechanics	Six or more errors in punctuation, capitalization, and spelling	Three to five errors in punctuation, capitalization, and spelling	Fewer than three errors in punctuation, capitalization, and spelling	
Presentation	Contains unreadable text	Readable, but with need for improvement	Neat and clearly readable	

- **Self-assessment:** A gotta-have-it list may take the form of a student self-evaluation check sheet. Here's an example:

Criteria	Missing I didn't do this.	Developing I cut some corners.	Solid I did this well.
I found two opposing opinions in the article.			
I showed a supporting detail for each opinion.			
My outline is organized so that the relationships between ideas make sense.			
I highlighted the opinion that is supported with stronger facts.			
I wrote a sentence to explain my reasoning following my outline.			

- **Peer feedback:** At least once per unit, you'll be encouraged to have students share their work with others and exchange peer feedback. A prompt to revisit classroom community norms accompanies those recommendations. Where peer feedback is recommended, the Teacher Guide includes specific instructions for peer feedback facilitation, and students receive guidance on giving peer feedback on an enhancement to the Exercise Page. Students also complete self-assessments of their own giving and receiving of feedback.
- **Revision opportunities:** The Teacher Guide makes intermittent recommendations to encourage students to revise their writing. It is important for students to regard writing as a useful version of the thought process and to acknowledge that thinking should change over time as learning builds knowledge.
- **Summative portfolio:** It is empowering for students to see how their writing (and their confidence in writing) has improved over time. Having students collect their writing artifacts in a portfolio for each unit covered in the school year provides a handy tool for reflection at the end of the course. You may also elect to partner with colleagues teaching English and language arts. If relevant alignment is present between courses, consider dual credit for students' writing assignments on science topics or for their entire portfolios.

### Supporting Mathematics

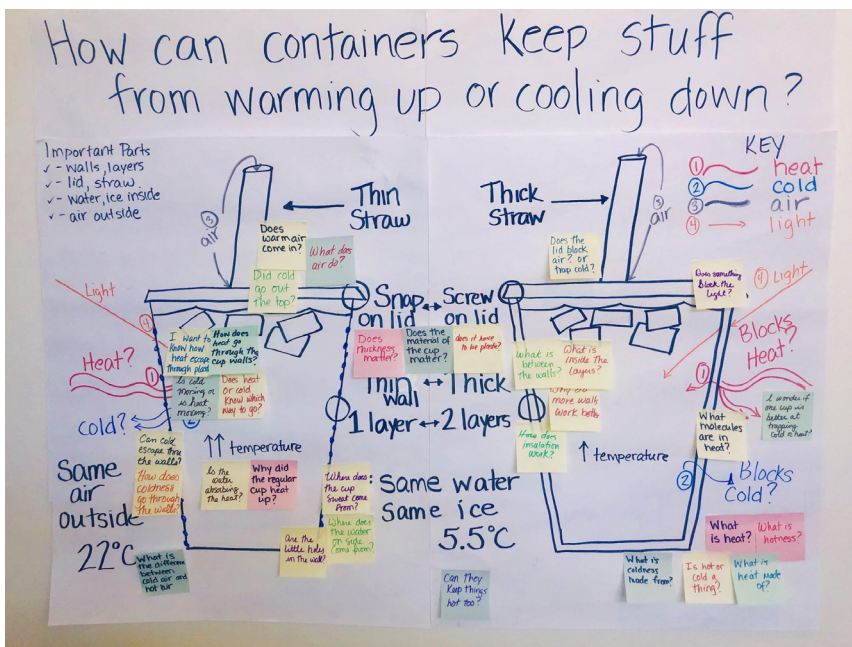
By design, the NGSS units connect to and reinforce the CCSS for mathematics. Where relevant and appropriate, the reading selections incorporate data that engage students in mathematical thinking as a part of understanding science concepts and help reinforce mathematical concepts or reasoning. The Teacher Guide provides support to break down analysis of the data or explain the problems and solutions in ways that are consistent with CCSS grade-level math instruction.

## D. Driving Question Board and Ideas for Investigations

### What is the Driving Question Board?

The Driving Question Board (DQB) is a tool used throughout the units as a way to generate, keep track of, and revisit student questions related to the anchoring phenomenon and related phenomena. Its use draws from work on project-based science learning (e.g., Singer et al., 2000; Weizman, Schwartz, & Fortus, 2010; Nordine & Torres, 2013). The DQB is a central support for the instructional model. It is often paired with an Ideas for Investigations chart that surfaces students' ideas for how they might investigate their questions on the DQB (see next page for examples).

The DQB is a visual representation of the class's shared mission of learning in the unit. It is publicly displayed to serve as a learning resource for the community and should be easily accessible to students to see and add to during the unit. DQBs can be constructed with sticky notes or sentence strips; they can be written on whiteboards or with shared software applications (e.g., Padlet, Mural, Jamboard). Wherever and however they are constructed, it is essential that the board be available to all students throughout the unit.



### When is the DQB used?

A DQB is introduced at the beginning of each unit during the Anchoring Phenomenon routine and then revisited by the class as part of the Navigation, Putting Pieces Together, and Problematizing routines. The role of a DQB changes over the course of a unit. Initially, the DQB enables the teacher and students to understand what students both know and do not know about the anchoring phenomenon. As the class revisits the DQB, students begin to answer questions on the DQB and can pose new questions.

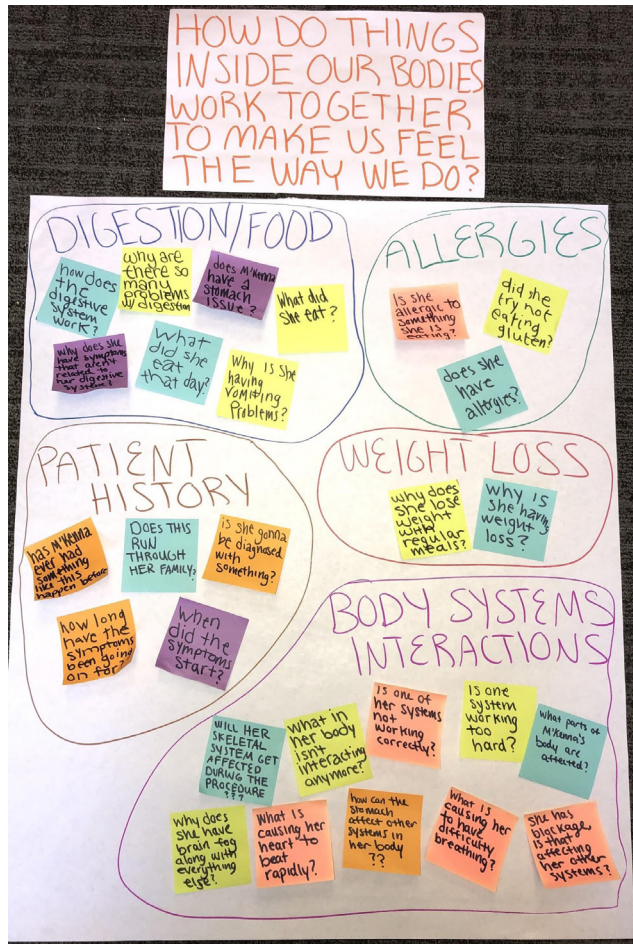
### How is the DQB used?

Students should understand that the DQB is meant not to set the agenda for the unit but to serve as a record of students' curiosities about phenomena and a way of documenting the progress that they make in understanding the phenomena under study. It is important that students understand there will be more questions on the DQB than can be answered during the unit.

Ideas for preparing a DQB for the start of each unit follow:

- Use a large sheet of poster board or chart paper to make the DQB. At the top, write the unit question.
- Make a space in the classroom for the DQB that is easily accessible to students. Students will need to regularly go up to the DQB (over the course of the unit) to post their questions and look at the questions that their peers have posted. Ideally, it is in a space where students can gather chairs around it and walk up to it to reach any part of it.
- Also create an Ideas for Investigations poster on chart paper to check off the ideas that the class pursues as it starts or finishes them. Add new ideas to the poster as students come up with them (additional pieces of chart paper may be needed).
- There are lots of ways to organize separate DQBs for multiple class sections. For example, one way is to put multiple charts on ring clips and flip the charts to display each class section's DQB.

Additional examples of DQBs and Ideas for Investigation charts are shown below:



## Possible Future Investigations

- Eat foods + see what they do
- Test to see what is in food
- Mash up food + put stomach acid on it
- Camera inside of M'Kenna
- Research what the digestive system is

Portions of Section D were adapted from tools and processes developed by NextGen Science Storylines at Northwestern University and from the work of the Investigating and Questioning Our World through Science and Technology Project at the University of Michigan, Northwestern University, and Michigan State University.

## E. Developing and Using Science and Engineering Practices

The science and engineering practices (SEPs) are intended to work together in such a way as to help students ask, investigate, and figure out science ideas. They represent the work that students do in the classroom. However, each unit cannot attend to all the elements of the SEPs; thus, each unit has identified specific science and engineering practices that will be the “focal” practices, or those for which the unit has emphasized the *development or use* of specific elements of the practices. Other SEPs are typically part of a unit, but the unit is not intentionally focused on developing those practices more fully, and thus they are not called out as focal practices. The focal practices are identified as part of the lesson-level performance expectations (LLPEs) and are discussed more fully in Section L (Assessment System).

If a practice is focal to the unit, additional instructional resources have been developed to attend to that SEP in particular. This might look like additional support to develop and modify a model with scaffolded diagrams to support students, along with a student self-assessment rubric. Or the support might look like sentence starters and self-assessment rubrics to support students in engaging in argument from evidence.

### A Note about Developing and Using Models

#### What are models, and how can they be used?

A model is a representation of a phenomenon that is used as a tool to explain how or why something in the world works the way it does (NGSS Lead States, 2013; McNeill, Katsh-Singer, & Pelletier, 2015). In general, a model is defined by how it is used. For example, scientific models are sensemaking tools that help us predict and explain the world, while engineering models are used for analyzing, testing, and designing solutions (Passmore, Schwarz, & Mankowski, 2017). In general, models can be diagrams, three-dimensional objects, mathematical representations, analogies, or computer simulations (NGSS Lead States, 2013). In these units, students build conceptual understanding of science by creating and revising models to explain phenomena. The course of a storyline can be described as a sequential process of developing and revising models to describe and explain different aspects of a phenomenon. Each section of a unit consists of an inquiry cycle with the goal of developing or improving a model of one aspect of a phenomenon. Students progress through the storyline by determining what aspects of the phenomenon they next need to explain. In addition to being the focus of students’ work, models also serve as external representations of students’ evolving understanding of the phenomenon.

#### Purpose

The purposes of engaging students in the development and use of models follow:

- **For students’ own sensemaking:** Making students’ ideas visible can help students consider the interrelationships between their ideas and consider non-visible components and processes that might be relevant for explaining the phenomenon.
- **To support students’ work with others:** Representations can be useful for students sharing their ideas with others to reach consensus.
- **To track progress in student learning over time:** Tracking the gradual development of ideas can help students individually and collectively make explicit what they’ve figured out, consider how their ideas are interrelated, and identify what is still needed.

#### How are models integrated into the units?

The units take a consistent approach to modeling so that students using these materials can develop and use models successfully within and across units. In each unit, teachers will see the following:

- In the Anchoring Phenomenon routine, students share their **initial model ideas** about the anchoring phenomenon and the causal mechanisms related to it. These model ideas might include a graphic organizer or chart of “What we think right now” or an initial diagram of a system. Ideas are typically developed individually and then shared as a class.

- Throughout the unit, students add their models ideas to a **Progress Tracker**. The Progress Tracker provides the space for students to document what they've figured out over time and consider what is needed to revise their models. At the same time, the class might use a gotta-have-it checklist. This is a list of ideas that must be included in the final model.

At the end of the unit, students, both individually and as a class, develop a **final explanatory model** that can be used to explain the anchoring phenomenon and related phenomena.

## F. Developing and Using Crosscutting Concepts

These units support students in transitioning from highly scaffolded experiences with crosscutting concepts (CCCs) to limited scaffolding. The materials can support this transition by providing explicit supports for CCCs at moments early in an instructional sequence and removing those supports over time as students become more autonomous in their use of CCCs. Ultimately, we want students to develop CCCs as strategies for reasoning about science that they can apply to a variety of phenomena—both in and out of school. To do this, students must learn how to use these strategies through personal experience, discussion, and practice in developing scientific explanations. Below are a few examples of how our materials can support students in this process:

- **Support students' use of CCCs to ask productive questions about phenomena.** Students tend to struggle in their generation of productive questions. Students also get “stuck” not knowing what kinds of questions they should ask. CCCs can be used by students to rethink a phenomenon and to identify productive kinds of questions they could ask about phenomena. Suggestions for how to use CCCs to help students generate productive questions are included in the Teacher Guide.
- **Provide principles and strategies to guide model-building and explanation.** The task of developing a model to explain a phenomenon can be daunting. The teacher materials provide guidance on how students can apply one or two CCCs in their model-building and explanation practice, cueing students to account for key elements they may otherwise miss. Prompts and checklists are provided in student materials to support them in applying these CCCs and reflecting on how they used them.
- **Sequence students' experiences of related phenomena in ways that engage students in analogical reasoning.** As students encounter new but related phenomena, CCCs are a way to make sense of the new phenomena even if students are unfamiliar with science ideas necessary to explain the new phenomena completely. Thus, the units are strategic in sequencing students' experiences of phenomena and encouraging them to see similarities and differences between these phenomena (analogical reasoning).

These units have integrated instructional resources that use CCCs to scaffold student sensemaking and discourse. One example includes integrating explicit question prompts to support the CCCs:

### **Example: Question Prompts** (STEM Teaching Tool #41, <http://stemteachingtools.org/brief/41>)

#### *Systems and Systems Models*

- What are the key components of the system?
- Are there key components that are invisible?
- How are the components related?
- How do the parts of the system work together?
- What would happen in the system if you increased X component?

#### *Structure and Function*

- What unique structures does this object/living thing have?
- What functions do the structures have?
- How does the structure facilitate the function?
- How does the shape of \_\_\_\_\_ help it function (or behave)?

### **Callouts to Highlight Crosscutting Concepts**

Callout boxes in the sidebar column are used to highlight CCCs where they are intended to be developed and/or used to help student sensemaking. In general, CCCs are particularly helpful in these key instructional moments:

- When we are stuck in generating questions and a CCC can help us focus our questions
- When we are stuck in interpreting data and a CCC can give us a new way to look at the data
- When we are setting boundaries/checklist/priorities for what to include in our models
- When it makes sense to reflect on how a CCC was helpful to our thinking
- When we are encountering a new but related phenomenon and we want to see how the new phenomenon is similar to or different from other phenomena we've explained

The purpose of a CCC is to help move students forward through a science storyline (e.g., “We are stuck, maybe thinking about \_\_\_\_\_ can give us some ideas of what’s going on here”). CCCs should always be coupled with other dimensions, not taught as stand-alone concepts. For example, when reflecting on the use of a CCC, it’s important to emphasize how the CCC worked in tandem with a practice or was critical for figuring out a disciplinary core idea (DCI). Take advantage of pairings of CCCs with DCIs or SEPs where possible, but look for three-dimensional moments as well. Examples of some pairings include the following (not an exhaustive list):

- Systems and system models with modeling
- Patterns with data analysis
- Scale, proportion, quantity with mathematical/computational thinking
- Structure/function with engineering design and/or biological systems
- Cause and effect with explanations

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*Portions of Section F are based on suggestions in STEM Teaching Tool #41 developed by the Institute for Science + Math Education at the University of Washington. The full tool is available at <http://stemteachingtools.org/brief/41>.*

## G. Attending to Equity

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Units are designed to promote equitable access to high-quality science learning experiences for all students. The units are designed to support learners who come from nondominant communities or from populations that are underrepresented in science, technology, engineering, and math (STEM) by offering students diverse entry points, experiences, and supports. Units use the following strategies to support equitable learning:

- **Focusing learning experiences on relevance to students and community purpose:** Units are designed to connect instruction to the interests, identities, and experiences of students and to the goals and needs of their communities. Strategies that have been used to achieve this goal include selecting phenomena that are interesting and accessible to a range of students and encouraging students to connect their experiences in class to their experiences in their homes and communities. For example, during the Anchoring Phenomenon routine in each unit, students identify related phenomena, which are then shared publicly to support and make visible these connections. This supports all students in being known and heard in the science classroom, as their ideas are used to further the community's understandings.
- **Supporting equitable sensemaking:** The central role of collaborative sensemaking (or "figuring out") in the units provides opportunities for students with diverse assets and perspectives to contribute meaningfully to the intellectual work of the classroom. Teachers should encourage students to express their ideas in language and discourse styles that they are comfortable with in order to open the conversation and sensemaking to all students. As described in Section F, discussion and discourse are essential features of the units. During the units, scientific language is developed as students experience science through the instructional routines. This language development occurs across multiple modalities, registers, and interactions, providing different supports for a range of student learners.
- **Using culturally responsive and sustaining practices:** The units value, make visible, and build on all students' ideas, including students from nondominant communities and populations that are underrepresented in STEM. Students' cultural and linguistic practices should be viewed as assets essential to the classroom community's efforts to make sense of natural phenomena, never as deficits or barriers to student learning. The role of the teacher is essential in this work, as the teacher develops and fosters a classroom community in which students' ideas are shared and central to the storyline development of a unit.
- **Supporting an expansive view of learning through formative assessment:** Opportunities to assess student thinking are embedded throughout the units. These opportunities are designed to enable teachers to observe students' authentic reasoning and scientific ideas. At numerous points in a unit, students demonstrate their understandings of concepts and their abilities to employ science and engineering practices through a variety of performances that do not privilege particular cultural or language practices. Teachers can then use the information garnered from these formative assessments to adapt their instruction to better meet the needs and interests of all learners in their classrooms and to more meaningfully connect to their students' lives.

Each unit was designed using these strategies, which are integrated throughout the instructional routines. In order to highlight the rationale behind these choices as well as to provide teachers with guidance on how to adapt the materials for their students, these strategies are discussed in the Teacher Guide in educative boxes titled "Attending to Equity." These educative boxes are embedded within the lessons in each unit to provide specific and just-in-time support for teachers. For example, in relation to the use of sentence starters in the student notebooks, an "Attending to Equity" box states: "Using sentence starters in science notebooks supports students in developing their ability to communicate in scientific ways. Sentence starters are particularly helpful for emergent multilingual students."

The units support these equity goals through several specific strategies, such as (1) integrating Universal Design for Learning (UDL) principles during the unit design process to reduce potential barriers and provide more accessible ways in which students can engage in learning experiences; (2) developing and supporting classroom norms that provide a safe learning culture; (3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas; and (4) supporting emerging multilingual students in science classrooms.

## H. Universal Design for Learning (UDL) Principles

The Universal Design for Learning (UDL) Guidelines are a tool that can be used to design learning experiences that meet the needs of all learners (CAST, 2018). Instructional designers and teachers can use these principles to create learning environments that reduce barriers to access for all students while keeping in mind the learning goals of the lesson. The three guiding principles of UDL are engagement, representation, and action and expression. These units are purposefully designed with multiple avenues for engagement, representation, and action and expression. The units offer built-in supports for teachers to highlight student assets and to address potential barriers to learning for their local student population.

Provide Multiple Means of Engagement	Provide Multiple Means of Representation	Provide Multiple Means of Action and Expression
Provide options for <b>recruiting interest</b> (7) 7.1 Optimize individual choice and autonomy 7.2 Optimize relevance, value, and authenticity 7.3 Minimize threats and distractions	Provide options for <b>perception</b> (1) 1.1 Offer ways of customizing the display of information 1.2 Offer alternatives for auditory information 1.3 Offer alternatives for visual information	Provide options for <b>physical action</b> (4) 4.1 Vary the methods for response and navigation 4.2 Optimize access to tools and assistive technologies
Provide options for <b>sustaining effort and persistence</b> (8) 8.1 Heighten salience of goals and objectives 8.2 Vary demands and resources to optimize challenge 8.3 Foster collaboration and community 8.4 Increase mastery-oriented feedback	Provide options for <b>language and symbols</b> (2) 2.1 Clarify vocabulary and symbols 2.2 Clarify syntax and structure 2.3 Support decoding of text, mathematical notation, and symbols 2.4 Promote understanding across languages 2.5 Illustrate through multiple media	Provide options for <b>expression and communication</b> (5) 5.1 Use multiple media for communication 5.2 Use multiple tools for construction and composition 5.3 Build fluencies with graduated levels of support for practice and performance
Provide options for <b>self-regulation</b> (9) 9.1 Promote expectations and beliefs that optimize motivation 9.2 Facilitate personal coping skills and strategies 9.3 Develop self-assessment and reflection	Provide options for <b>comprehension</b> (3) 3.1 Activate or supply background knowledge 3.2 Highlight patterns, critical features, big ideas, and relationships 3.3 Guide information processing and visualization 3.4 Maximize transfer and generalization	Provide options for <b>executive functions</b> (6) 6.1 Guide appropriate goal setting 6.2 Support planning and strategy development 6.3 Facilitate managing information and resources 6.4 Enhance capacity for monitoring progress

Source: Modified from CAST (2018), *Universal Design for Learning Guidelines, Version 2.2*, graphic organizer found at <http://udlguidelines.cast.org>

## Engagement

“Learners differ markedly in the ways in which they can be engaged or motivated to learn . . . there is not one means of engagement that will be optimal for all learners in all contexts; providing multiple options for engagement is essential” (CAST, 2018). These units use an anchoring phenomenon that is complex and interesting in order to both stimulate and maintain student engagement throughout each unit. In the UDL framework, teachers can foster student engagement by recruiting student interests, supporting sustained effort and persistence, and providing options for students to self-regulate. Students generate questions that they are interested in answering, allowing them to set their own purposes for learning. Classes repeatedly revisit the anchoring phenomenon and guiding questions in discussions and their Progress Trackers, maintaining student investment in the work of figuring out the phenomenon. Individual student progress is recorded in their science notebooks, and class progress is displayed through charts and visuals in the classroom, providing constant feedback to students about what has been accomplished through their work. The units provide guidance to teachers for developing a safe space for students to share and build on ideas through developing and revisiting communication norms. Teachers may choose to use optional peer- and self-assessment resources that are provided with each unit in order to support students’ capacity for reflection.

### An Example of the Engagement Principle

One of the components of the Engagement principle is to minimize threats and distractions, creating a safe space for all learners. The first unit for every grade level (One-Way Mirror, Bath Bombs, and Collisions) has built-in norm-building and norm-revisiting activities embedded throughout the lessons. The callout box below is in Lesson 1 of One-Way Mirror and introduces and explains the Scientists Circle construct as a support for student engagement:

**Universal Design for Learning:** *Having students sit in a circle so they can see and face one another can help support engagement and build a sense of shared mission and a community of learners working together. Returning to this Scientists Circle throughout the course of the unit to take stock of what the class has figured out and where they need to go next will be an important tool in helping the class take on greater agency in steering the direction of their learning. This circle will also help build a sense of pride in their work. You may want to inform students that professional scientists collaborate with one another to brainstorm, discuss, and review their work also.*

## Representation

These units require students to use science concepts to figure out explanations of or solutions to natural phenomena. However, what is provided or presented to students can enhance or deter a learner’s ability to engage in rich discussion and thinking. Representation focuses on what is presented in front of students to engage with the intended goals of learning. Multiple representations are meant to provide different access points for a learner’s participation and figuring out. The units do not value one presentation of information to students; rather, they incorporate models, data tables, texts, graphs, videos, and discussions. The units and lessons are carefully designed to incorporate multiple access points for all learners, and they provide callout boxes for further guidance for diverse populations. Representation can be altered in regard to perception, language and symbols, and comprehension. These three Universal Design for Learning guidelines help you see how instruction can be appropriately represented to accentuate the assets and mitigate the barriers of your diverse learners regarding rich figuring out of science.

### An Example of the Representation Principle

In the Everest unit, Lesson 1, guidance is provided for instructors within a callout box labeled with “Equity” and “Universal Design for Learning.” These callout boxes provide supplemental guidance for multiple access points for learning while maintaining the goal of students figuring out science ideas.

**Universal Design for Learning:** *Students engage with the anchoring phenomenon using multiple forms of media. Students initially explore the phenomenon of Mt. Everest shifting and growing taller as they watch two videos and read a text. Later in the lesson, they engage with a simulation (Seismic Explorer) to help identify patterns in locations of earthquakes at Mt. Everest and beyond. Providing multiple forms of media to present the information provides more access for the diverse learners in your classroom.*

## Action and Expression

The goal of the Action and Expression principle is to ensure that learners can fully communicate what they know through varied forms of action or expression. The units provide opportunities for students to develop strategies (e.g., self-reflection, planning, goal setting) and skills (e.g., speaking, writing, assembling physical models) that enable them to demonstrate what they know. The units contain several features that support students in planning, organizing, and evaluating their own learning across the unit. For example, each unit identifies opportunities for self-assessment, and units often include student-facing tools like discussion protocols and self-assessment rubrics that support students in planning for and self-evaluating their learning and growth across the unit. Additionally, the units provide multiple means for students to express their developing understandings and to show their learning. For example, the science notebook is a tool for students to record their thinking and use words, pictures, and symbols in ways that help them make sense of the investigations and science ideas that emerge. Further, on formative and summative assessments, students are asked to write or draw their current thinking, allowing students to show their learning in a variety of formats.

### An Example of the Action and Expression Principle

In the Bath Bombs unit, Lesson 5, guidance is provided for instructors within a callout box labeled with “Universal Design for Learning.” These callout boxes provide supplemental guidance to teachers for supporting students in choosing the way they express their thinking as they figure out science ideas. This particular callout box involves guidance on how to support students in using multiple means to express their verbal and written arguments:

**Universal Design for Learning:** *This discussion is one of many different ways students will express their understanding of types and forms of arguments they can make using property data related to gases. Other forms of expression in this lesson include*

- *annotating the Common Gases handout;*
- *predicting and discussing the results of firsthand investigations as they happen;*
- *writing a predictive explanation using sentence scaffolds;*
- *verbally sharing their conclusions using a discussion protocol;*
- *snapping their fingers and lightly tapping their feet in response to oral arguments;*
- *writing a final argument.*

*Providing students varied and multiple ways to express their understanding helps support them in accessing, building, and ultimately internalizing the strategies used in arguing from evidence in general, and not just for this specific case and context.*

## UDL and differentiation work together to support student learning.

These units are designed in such a way as to use the principles of Universal Design for Learning to provide equitable and accessible learning from the outset of the units. But we acknowledge that teachers will still need to find ways to accommodate activities in the materials to better fit with student learning needs or the needs and resources of the classroom. There are many ways differentiation occurs in classroom settings. Teachers address their students’ diverse learning needs in terms of student readiness, interest, and special learning needs and can make adjustments in terms of the content, the learning processes, and the student products that result from a learning experience (Tomlinson & Allan, 2000). The units are also designed with differentiation in mind, allowing teachers to adapt the materials as necessary without diminishing the learning experiences for students.

These units specifically include differentiation strategies in the following sections of the units: teacher background knowledge, the lesson-level “Where we are going” and “Where we are not going” sections, and the assessment overview and guidance tables. These sections provide teachers with information about adapting the content, process, or product of the lessons. Teachers can also find differentiation guidance within the Learning Plans in three particular types of callouts:

- **Equity** callouts focus on moments in instruction in which a certain population may benefit from a particular strategy, such as supporting language development for emergent multilingual learners, providing extended learning opportunities or readings for students with high interest, or providing specific strategies for students with special learning needs.
- **Alternate Activity** callouts provide guidance to teachers about going further or streamlining activities based on student progress and/or completing different learning activities. These can be particularly helpful for students with high interest or for students or classrooms that need modified units based on availability of time or access to resources.
- **Additional Guidance** callouts provide more specific instructions to teachers on how to make a learning activity successful based on their students’ needs. These callout boxes provide a variety of instructions to modify the timing, grouping, or resources for a particular activity.

## Conclusion

The UDL Guidelines informed the design of the instructional materials to minimize barriers and create pathways for diverse learners. Diverse learners include those who are culturally and linguistically diverse, have a disability, are emerging multilingual learners (EMLs), and/or are considered gifted and talented. Each individual student can be recognized as part of multiple groups and has unique characteristics specific to that individual. The routines and strategies built into the units create different pathways for individual students. Furthermore, the callout boxes provide additional strategies teachers can use to adapt activities and modify the units to better meet the needs and leverage the resources of their specific learners.

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*Section H draws directly from the work of: CAST, (2018). Universal Design for Learning Guidelines version 2.2. Retrieved from <http://udlguidelines.cast.org> and portions related to differentiation were developed with ideas from Tomlinson, C. A., & Allan, S. D. (2000). Leadership for differentiating schools and classrooms. Alexandria, VA: ASCD.*

## I. Classroom Culture and Norms

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### Purpose of Norms

The instructional materials rely on students collectively figuring out science ideas together through productive discourse and classroom talk. This requires a classroom culture in which all students feel like they belong and that it is safe to participate, share their ideas, disagree, and productively struggle together. Classrooms are learning spaces in which students' varied cultural and linguistic experiences and ways of knowing are an integral part of the learning community's sensemaking and can be leveraged to help develop and push all students' learning forward. The development and ongoing use of classroom norms can support safe and equitable student participation in collaborative sensemaking.

### Norms to Support Productive and Equitable Participation

#### Respectful

In order for students to take the risk of making sense of complex ideas with their peers, they need to feel safe and know that they will not be ridiculed or mocked. Establishing and enforcing norms that work to make the classroom a safe space to share is a prerequisite for productive talk. Providing each other with support and encouragement, sharing time to talk, and critiquing the ideas we are working with but not the *people* we are working with are some norms that can support respect. Including students in conversations around establishing such classroom norms can be very helpful. For instance, have a conversation with students about what might prevent someone from participating in a discussion. Then brainstorm together agreements the class can make that might help **all** students feel comfortable sharing ideas. Explicitly addressing the idea that disagreements are an essential part of making sense in science and that these disagreements can sometimes feel like conflict and then brainstorming ways that we can disagree with others' *ideas* is also essential. Additionally, working together to figure out reasonable and realistic consequences when someone says something disrespectful can help build the community norms and help students know what to expect as they continually work toward respectful discussions. These conversations can take place at the beginning of the school year and then throughout the school year to ensure that all students continue feeling supported and safe sharing their ideas in the classroom.

#### Equitable

If we value the importance of discourse in helping us figure out science ideas together, then *all* students need to have access to the conversation. This does not mean that every student has to talk during every discussion; however, it should be clear that they are welcome and expected to participate. Discussions are not equitable if a few students dominate the conversation or if other students assume that certain students will carry the discussion. Norms to support equitable discussions include monitoring our own time spent talking, encouraging others' voices who we have not heard from yet, and recognizing and valuing that people think, share, and represent their ideas in different ways. Have a discussion with your students about ways to make sure that everyone feels welcome to join the conversation. When we engage students in academically productive talk, we are asking students to talk in ways they may not be comfortable with and would not be expected to talk at home. For students who are by nature very shy, emerging multilingual students, students with high-frequency learning needs, or students new to academic discussions, scaffolding and support (from both the teacher and their peers) may be required to help students formulate arguments and explanations in a way that others can hear, make sense of, and understand. One strategy to help them who may be reluctant to participate is to ask them to simply repeat what someone else has said in order to help clarify a classmate's idea. This strategy, along with revoicing an idea, allows students to begin to be involved and allows others to hear the idea again so that they can work with it. Additionally, as students begin to see that these discussions are about making sense and thinking deeply, versus getting the right answer, they may feel more comfortable sharing.

#### Committed to Our Community

We are working to "get smarter together." This means that *we* learn together, and it is not enough to just share our ideas without connecting to others' ideas. Establishing norms around being prepared and focused during discussions is important. Developing the idea that we all have a responsibility to our learning community to come prepared, share our thinking so that others can understand, and listen carefully and ask questions is important. Encouraging

students to contribute ideas even when they are not sure and celebrating their ideas (both correct and incorrect) go a long way in supporting these norms.

## Moving Our Science Thinking Forward

We engage in these academically productive discussions in order to deepen our understanding and make sense of complex science ideas. Here, we are talking about rigorous conversations where the focus is on using evidence and reasoning. Wrong or incomplete ideas are important resources and welcome opportunities to explore together as a community. Students will be asked to explain their thinking and say why they made a particular claim, regardless of whether their ideas are scientifically accurate or not. It is important to be aware that these types of questions traditionally signal to students that they are wrong. Consequently, it is important to establish norms around asking questions and working together to move our science thinking forward. We need to explicitly teach students how to use and build on others' ideas as well as the importance of providing and asking for evidence, encouraging others to clarify their reasoning, and being open to changing our minds based on new evidence. You can explain the kinds of talk moves you might use and then ask them how it makes them feel. For example, you might say, "I will ask you, 'Why do you think that?'" If students indicate that such questions make them feel like they are wrong and not want to participate any further, you can explain and reinforce the importance of sharing their reasoning and how critical it is to help everyone learn. The more explicit we can be with the types of moves we (and they) can use to help move our science thinking forward, the more comfortable students can become.

### Important questions to consider:

- Do you want students to participate in co-constructing classroom norms?
- Do you want the same set of norms for every section of science you teach?
- Do you want to work with your team teachers to establish a shared set of norms for students across all their classes?
- What kinds of consequences will you enforce if students do not follow the norms?
- How often will you check in with students about the norms and whether any need to be revisited or added to?

### Strategies for Developing Community Norms

When setting up community norms, students should understand how norms help everyone in the community understand what is expected of them. Two strategies for setting up norms are as follows:

- **Give students a set of norms as a starting point.** Hand out a set of community norms at the start of the year. Have students discuss what the norms mean in their own words. Elicit from students the reasons these are good norms. Also, ask students which norms they feel might be challenging and why. Provide space for students to edit or add to the norms if students believe something is missing.
- **Co-construct norms with students.** Explain what norms are and why we need them for productive science talk and classroom culture. Have students co-construct norms, first sharing ideas in their small group and then sharing out with the whole class. Compile a list of agreed-upon community norms. As the teacher, you can add norms that may be missing from the list. Make sure to explain to students how you think the norm you added is helpful so that they are clear about why you are adding it to the list.

### Tips for Making Norm-Setting Successful

- Every classroom community is unique, and the norms for guiding behaviors in the community should fit the unique needs and experiences of the members. Consider the unique needs and experiences of your students and how much support they will need in establishing and following norms for productive talk in science.
- Make the classroom norms meaningful to the students you work with. A rigid list of "norms" given to students with no student input simply becomes a list of "classroom rules" and not a shared set of norms.
- Devote enough class time to co-constructing norms or discussing a set of norms. This will set clear expectations for everyone.

## Strategies for Actively Using and Reinforcing Community Norms

- **Help students understand the rationale for norms.** In the first few weeks using the norms, when pushing students to practice specific discourse moves, ask students to reflect on why you're pushing them.
  - Why am I asking you to repeat what another student said?
  - Why am I asking for your reasoning?
  - Why is it okay to disagree with another student's ideas? How does doing so move everyone's science understanding forward?
- **Conduct whole-class-check ins.** Discussing progress with the norms regularly helps students understand that norms are expected behavior all the time, not just in the beginning of the school year or when something has gone "wrong". Check in periodically with the class, asking students to reflect on the following:
  - How did we do today in our discussion?
  - What talk moves or norms do we feel we were successful with?
  - What talk moves or norms do we need to work on?
- **Have students conduct partner check-ins.** At the start of class, have each student pick a norm they would like to focus on for the day and share that with a partner. At the end of the day, give partners time to share how they did with their focal norm. This elevates the community norms as students become more accountable for their actions and helps students actively use and improve upon them.

A standard set of norms is found in the table that follows. These are provided with the first units of each grade level but serve only as a guide for classrooms. Additionally, the table provides example talk moves aligned to the norms.

Classroom Norms		Talk Moves to Support Norms
<p><b>Respectful</b></p> <p>Our classroom is a safe space to share.</p>	<ul style="list-style-type: none"> <li>• We provide each other with support and encouragement.</li> <li>• We share our time to talk. We do this by giving others time to think and share.</li> <li>• We critique the <i>ideas</i> we are working with but not the <i>people</i> we are working with.</li> </ul>	<ul style="list-style-type: none"> <li>• "Daniel, that's a great idea. How do you think we could investigate it?"</li> <li>• Give time to think using wait time, turn and talk, or individual writing time, such as stop and jot.</li> <li>• "Why do you disagree with Juan's idea?" rather than "Why do you disagree with Juan?"</li> </ul>
<p><b>Equitable</b></p> <p>Everyone's participation and ideas are valuable.</p>	<ul style="list-style-type: none"> <li>• We monitor our own time spent talking.</li> <li>• We encourage others' voices who we have not heard from yet.</li> <li>• We recognize and value that people think, share, and represent their ideas in different ways.</li> </ul>	<ul style="list-style-type: none"> <li>• "I'd like to hear from someone who hasn't yet gotten a chance to talk."</li> <li>• "How did we do today in our discussion making space to hear from everyone?"</li> <li>• "The way Shayna described _____ really helped me think about it in a different way."</li> </ul>
<p><b>Committed to our community</b></p> <p>We learn together.</p>	<ul style="list-style-type: none"> <li>• We come prepared to work toward a common goal.</li> <li>• We share our own thinking to help us all learn.</li> <li>• We listen carefully and ask questions to help us understand everyone's ideas.</li> <li>• We speak clearly and loud enough so everyone can hear.</li> </ul>	<ul style="list-style-type: none"> <li>• "Who can paraphrase what Selma just said?"</li> <li>• "What did your partner say?"</li> <li>• "What questions do you have for Shereen about her idea?"</li> <li>• "I think I heard what you said, but can you say it again to make sure everyone heard?"</li> </ul>

Classroom Norms		Talk Moves to Support Norms
<p><b>Moving our science thinking forward</b></p> <p>We work together to figure things out.</p>	<ul style="list-style-type: none"> <li>We use and build on others' ideas.</li> <li>We use evidence to support our ideas, ask for evidence from others, and suggest ways to get additional evidence.</li> <li>We are open to changing our minds.</li> <li>We challenge ourselves to think in new ways.</li> </ul>	<ul style="list-style-type: none"> <li>"Why do you think that? What's your evidence?"</li> <li>"Do you agree or disagree with what Juan said? Why?"</li> <li>"Who can add on to Jerome's idea?"</li> <li>"Did you see something represented in someone else's work that changes how you are thinking about _____?"</li> </ul>

Portions of Section I draw from the work of the Science Education Research Partnership (SERP) and the Next Generation Science Exemplar Project (NGSX). Two specific resources are: Michaels, S., & O'Connor, C. (2014). *Establishing norms: Laying the foundations for academically productive talk* and O'Connor, C., Ruegg, E., & Cassell, C. (2017). *Establishing classroom discussion norms*.

## J. Supporting Discussion

The negotiation and construction of scientific ideas through talk is a central part of the program's vision. Discussion is the glue that connects science and engineering practices to one another, and it connects those practices to disciplinary core ideas and crosscutting concepts. Discussion is the way that a classroom community makes sense of what it is investigating. Finally, discussion is the key to a classroom learning community in which all students' ideas are shared and valued. The instructional model builds upon prior work in the science education field on classroom discourse, productive talk, and support for discussion (e.g., Michaels & O'Connor, 2012; 2015; 2017) and tools developed by the Next Generation Science Exemplar Project (Michaels & Moon, 2016; Reiser et al., 2017). The units use specific types of discussions to help draw out student ideas, negotiate and refine them, and support students in communicating with one another in scientific ways:

- Initial ideas discussions
- Building understandings discussions
- Consensus discussions

Each type of discussion serves a different complementary purpose and is useful in different phases of a lesson or unit. Regardless of the type of discussion, it is always important to consider how to make it possible for all students to contribute and work with one another's ideas. Teachers are encouraged to set aside time for students to think individually and in small groups as part of a discussion plan.

### Initial Ideas Discussions

#### Purpose

- To share students' initial ideas and experiences
- To help students make connections between what they are figuring out in the classroom and what they have seen or experienced outside of school
- To provide a chance for students to share and make sense of ideas—even if those ideas are tentative or still being formed

#### When This Type of Discussion Is Useful

- During the Anchoring Phenomenon routine
- During the Investigation routine
- During the Problematizing routine
- Any time students are beginning the process of making sense of a phenomenon

### Strategies for This Type of Discussion

1. Provide a way for all students to surface their ideas (think-pair-share is one strategy).
2. Encourage students to use multimodal communication to express their thinking (such as gestures, graphical representations, etc.), and allow them to use all of their linguistic resources (this could include multiple languages).
3. Give students a chance to clarify one another's ideas and to ask other students to expand on what they have said and explain their thinking.
4. Ask a student to summarize the class's initial ideas.
5. Ask students how they might test or further explore their ideas.

## Building Understandings Discussions

### Purpose

- To share, connect, critique, and build on others' findings, claims, evidence, and explanations
- To provide the teacher and students with an opportunity to clarify which aspects of the questions and problems the class has identified have been addressed and developed and which need further investigation

### When This Type of Discussion Is Useful

- During the Navigation routine
- During the Investigation routine
- During the Putting Pieces Together routine
- Any time students have been exploring new ideas

### Strategies for This Type of Discussion

1. Invite a student or group to share their current explanatory model or design solution with the class.
2. Invite others to ask questions about the model or solution, suggest additions to it, and critique the model or solution.
3. Invite a second student or group of students to share their model or solution, and then invite response and critique.
4. Ask students how the proposed models or solutions are similar and different.
5. Invite the class to consider what might need to be revised in the models or solutions based on the models seen and the evidence that has thus far been gathered and made sense of.

## Consensus Discussions

### Purpose

- To collectively work toward a common (class-level) explanation or model; includes capturing the areas of agreement for which the class has evidence as well as areas where the class still disagrees and might need further evidence
- To take stock of where the class is in its figuring out and support the public revision of earlier ideas

### When This Type of Discussion Is Useful

- During the Putting Pieces Together routine
- Any time students have had the opportunity to construct new understandings

## Strategies for This Type of Discussion

1. Ask students to take stock of where the class has been and what it has figured out, offering conjectures or pieces of a model, explanation, or solution.
2. Ask students to offer proposals for a consensus model, explanation, or solution.
3. Ask the class who agrees with, disagrees with, has alternatives for, or has questions about each proposed idea.
4. Ask students to support or challenge proposed models, explanations, or solutions and to say what evidence is the basis for their support or critique.
5. Ask students to propose a modification to the model, explanation, or solution based on input from the class.
6. Scribe what the class agrees on, and track where the class has open questions or disagreements.

## Making Participation Equitable during Discussions

Discussions are a key point during instruction in which students' thinking, experiences, and ideas for further exploration can be surfaced and leveraged in the classroom. Below are some strategies for supporting equitable participation during discussions:

- In eliciting initial ideas or initial questions, the goal is to get as many ideas on the table as possible. Consider asking students to "write and pass" a sheet of paper around their group until they have at least 10 items. That way, all students get a chance to contribute, to see others' ideas, and to add their thinking in a low-stakes way. Make sure to let students know that these ideas can be expressed in different ways (e.g, pictures, graphs) and that they are not limited to words in English.
- Use student groups' feedback to prioritize ideas and questions for the class investigations. For example, have groups pass their written lists to another group, who will circle the two "most pressing questions" on the list. As they do this, you can circulate and find the top four or five questions the class agrees on—this is your final student-generated list of driving questions.
- Think about what kinds of support your students might need to be able to ask each other to clarify and summarize questions without being critical or evaluative. You might try using the [metaphor of a coach](#) to introduce these think-pair-share routines. You could try telling students, "This is about helping your partners practice as scientists and supporting them in their thinking, so you're going to ask questions about their ideas and encourage them to further develop their current understandings, and for now, your ideas will stay on the sideline. Then we'll switch, and you'll get a chance to share your ideas as you are coached by your partners."
- Have sentence starters available for students so that they know what they might ask to push their partners further (e.g., "You mentioned \_\_\_\_\_, can you say more about that?"), but also have sentence starters available to slow down the fast explainers (e.g., "Wait—you said that really fast. Can you say that again?") (see [Talk Science](#) for a portfolio of useful prompts for many different challenges in facilitating productive academic talk).
- Consider a variety of ways for students to have these discussions, such as in a gallery walk where one person stays by the group's model, explanation, or solution to invite and respond to critique while other students ask pressing questions. During critique-based interactions, it is important to emphasize "making our ideas stronger," not "showing we have the best ideas," and that it is important to critique the idea, not the person. You can also encourage students to take a "coaching" stance here; their role is to ask questions that support others' ideas and to encourage other students to speak up when something needs to be clarified or repeated.
- Many students are not comfortable being the "only one" who voices a disagreement, a discontent, or a potentially wrong idea, so ask students to use the think-pair-share routine and to carefully listen to their partner's ideas. Then ask students to think about what they heard their partner saying, and ask the room if their partner's ideas are represented in the class discussion. This supports all students in sharing, listening, and being heard and in having their ideas represented and used to further the classroom community's developing understandings.
- Framing the goal of the discussion as "reaching consensus" means that there are many reasons for students to raise questions. A student doesn't have to say they disagree (which may seem like challenging something others have already said they like) but instead can articulate that they aren't persuaded yet and need more help following the chain of argument. Providing sentence starters like "I am not following how you got to . . ." and "I am not convinced that . . ." could be helpful.

## Discussion Planning and Reflection Tool

Use this tool to intentionally plan for, facilitate, and reflect on key instructional moments in the classroom. It is not intended that this tool be used for every discussion; rather, choose one or two moments within a unit where discussion is particularly beneficial for advancing the storyline. Below are lists of questions for you to consider before, during, and after the focal discussions.

### Before the discussion:

1. What is the question students are trying to answer through this discussion?
2. What is the intended outcome of the discussion? (E.g., coming to consensus on something students just experienced? Figuring out improvements to the class model? Designing an investigation? Getting students to realize they have new questions?)
3. What are the key elements of the model or explanation you want the students to grapple with?
4. What other ideas might students have? What questions might they ask?
5. Where will you be going next, and how will this influence how you wrap up the discussion? (E.g., problematize? Continue investigation? Design an investigation? Apply ideas back to the anchor?)

### Leading the discussion:

1. What will you say to launch the discussion?
2. What are some things you will say to encourage your students to work with one another's ideas?
3. If students seem to think they have explained the phenomenon but you know they need to go deeper, what kinds of questions could you ask to help students see the need to extend or revise their explanations?
4. What will you say to help close the discussion to establish a public record of what it is you all agree on and/or what new questions the class has?

### After the discussion:

1. What ideas and reasoning did you hear? How would you describe the groups' understanding of the ideas you identified in your planning?
2. What went well in the discussion?
3. What was challenging? Why do you think it was challenging?
4. Think about a moment when you weren't sure what to do. What *did* you do, and why? And what was the result?
5. Is there anything you would do differently if you could do the discussion over?

## Questioning Strategies to Support Discussions

To engage students in these types of discussions, the units suggest four questioning strategies for teachers to use to promote student discourse. These questioning strategies are intended to surface, challenge, and move forward student thinking while also fostering a community of science learners. While they are initially intended as questions that teachers can use, if they are incorporated as part of the norms of classroom culture, students will also begin asking these questions of each other. These questioning strategies are (1) elicit questions, (2) probe or clarify questions, (3) challenge questions, and (4) questions to support science discourse.

### Elicit Questions

The goal of *eliciting* questions is to learn about students' prior knowledge and experiences, current understandings, and ways of making sense—whether their ideas are scientifically accurate or not. The more teachers understand how students are thinking about phenomena and science ideas, the better their instruction can be adapted to challenge misconceptions and to support the building of more scientific, evidence-based understandings. Elicit questions also help students see that different people have different ideas. Eliciting student ideas demonstrates to students that all ideas are valued. Student thinking becomes a resource (rather than an obstacle) that starts the process of making sense of new ideas. Students can construct new knowledge using their everyday ideas as stepping-stones toward deeper understanding.

Examples of elicit questions include the following:

- What are your ideas about (phenomenon)?
- What are your ideas about how to solve (this design challenge)?
- What experiences do you have that might help you think about (this phenomenon)?
- What are some ways we could test our initial thinking?
- What questions do we need to answer to solve the design challenge / explain the phenomenon?
- What are some of the key components of your model/solution?
- Could someone restate our question (or our charge)? What are we building consensus about?

### **Probe or Clarify Questions**

The purpose of asking probing questions is to get more information about a student's thinking and understanding. It is not designed to teach new ideas or to "lead" students to a correct answer. Such questions can ask the student to give more information ("Can you tell me more?"), or they can ask a student to clarify their thinking ("Did you mean . . .?"). Like questions that elicit student ideas, questions that probe student thinking help you learn about students' prior knowledge, misconceptions, experiences, and ways of making sense. The more you can understand how students are thinking about science ideas and phenomena, the better you can adapt your instruction to challenge their misconceptions and to support them in changing their ideas toward more scientific, evidence-based understandings.

Examples of probe or clarify questions include the following:

- Can you say more about that?
- Where does that idea come from?
- Is that something you've heard, observed, or experienced before?
- What do you mean when you say the word "X"?
- Could you tell us more about that component of your model/solution?
- Can you clarify \_\_\_\_\_ aspect of your model/solution?
- Could you clarify the link you are making between your explanation and the evidence?

### **Challenge Questions**

Questions that challenge student thinking are designed to push students to think further, to reconsider their thinking, to make a new connection, and/or to use new science vocabulary. Questions that challenge student thinking do not ask students to simply state a vocabulary term or definition but rather ask them to use science ideas in a meaningful way. *Challenge* questions avoid leading directly to the right answer and focus instead on guiding student thinking toward a new concept or deeper understanding. The goal is to get students thinking more deeply while also scaffolding or guiding their thinking toward more scientific understandings.

Examples of challenge questions include the following:

- How does this model explain the evidence we have so far about this phenomenon?
- How does this solution fit the criteria we identified for a possible solution?
- Is there any evidence you know of that's not accounted for in your model/solution?
- How could we modify what we have so that we account for the evidence we agree is important to consider?
- Is there more evidence or clarification needed before we can come to an agreement? What might that be?

### **Questions to Support Science Discourse**






Supporting science discourse in classrooms means engaging students in learning how to communicate effectively in the scientific community of the classroom, understanding the norms for presenting scientific arguments and evidence, and practicing productive social interactions with peers in the context of science investigations.









**Teacher moves to support science discourse:** Teachers can use and model questions with the purpose of explicitly supporting students in communicating in scientific ways with one another. Through these types of questions, students can be encouraged to listen to one another, consider each other's perspectives, and then decide

how to best communicate their own thinking and evidence to peers. Explicitly helping students structure their communication with one another is an important part of building a scientific community within the classroom where ideas are shared, challenged, refined, and built upon. Examples of supporting science discourse questions include the following:

- Did anyone have a similar question to that?
- Does anyone have a different question that we haven't talked about yet?
- Can anyone add on to this idea?
- Who has a different way of thinking about this topic?
- Who can summarize some of the ideas we've heard today?
- Is this a complete summary? Can someone add what they think is missing?
- What questions do you have for this group about their model/solution?
- What do the rest of you think of that idea?
- Who feels like their idea is not quite represented here?
- Would anyone have put this point a different way?

**Students engaging in science discourse with one another:** The above questioning strategies are teacher talk moves that can prompt students to share their initial ideas, revise or clarify those ideas, and challenge those ideas in productive ways as well as support students in assembling their ideas. However, a critical aspect of science classroom discourse is for students to begin to communicate naturally with one another as their thinking develops and changes over the course of learning. The teacher's role can then shift away from being the intermediary in discussions and toward becoming an observer of student talk with one another, noting the progression of student thinking and areas where disagreement still exists, which allows the teacher to plan for future instruction. The Communicating in Scientific Ways chart is an example of one resource that provides students with visible sentence stems to help prompt their communication with one another. A printable version of this can be found with the online resources for each unit.

How We Figure Things Out	Symbol	How We Communicate
1. Ask why and how questions		How come ... ? I wonder ... Why ... ? How do they know that ... ?
2. Observe		I see ... I noticed ... I recorded ... I measured ...
3. Organize data and observations		I see a pattern ... I think we could make a graph ... Let's make a chart ...
4. Think of an idea, claim, prediction, or model to explain your data and observations		My idea is ... I think that ... We could draw a picture to show ... I think it looks like this ...
5. Give evidence for your idea or claim		My evidence is ... The reason I think that is ... I think it's true because ...

How We Figure Things Out	Symbol	How We Communicate
6. Reason from evidence or models to explain your data and observations		The reason I think my evidence supports my claim is because . . . The model shows that . . .
7. Listen to others' ideas and ask clarifying questions		Are you saying that . . . ? What do you mean when you say . . . ? What is your evidence? Can you say more about . . . ?
8. Agree or disagree with others' ideas		I agree with _____ because . . . I agree with you, but I also think . . . I disagree with _____ because . . . I know where you are coming from, but I have a different idea . . . I am thinking about it differently . . .
9. Add on to someone else's idea		I want to piggyback on April's idea. I want to add to what Jeremiah said.
10. Search for new ideas from other sources		We could get some new ideas from . . .
11. Consider if new ideas make sense		That idea makes sense to me because . . . That idea doesn't make sense because . . . What's their evidence?
12. Suggest an experiment or activity to get more evidence or to answer a new question		What if we . . . ? We could get better evidence if we . . .
13. Let your ideas change and grow		I think I'm changing my idea. I have something to add to my idea.

Portions of Section J were adapted from from tools and processes developed by NextGen Science Storylines at Northwestern University and from the Next Generation Science Exemplar System Project (NGSX) at Clark University and Tidemark Institute, from Science Teachers Learning from Lesson Analysis (STeLLA®) project at BSCS Science Learning, and the work of the Investigating and Questioning Our World through Science and Technology Project at the University of Michigan, Northwestern University, and Michigan State University. This material is based upon work supported by the National Science Foundation under Award Nos. 0310721, 0918277, 0957996, 1118643, 1220635, 1321242, 1503280, 1725389, and 1813127. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

## K. Supporting Emerging Multilingual Learners

### Who are emerging multilingual learners (EMLs)?

We intentionally use the term *emerging multilingual learner* (EML) because it is asset-oriented, highlighting students' multiple resources and knowledge of languages in addition to English. An estimated five million students, or 10 percent of the total student population in the United States, are EMLs (this is likely an underestimation because these numbers only reflect students who have been legally identified as English language learners, or ELLs, and thus are entitled, through state and federal laws, to academic coursework with specialized support to help them reach certain thresholds of English proficiency). EMLs are not a uniform student group. The term *EMLs* captures an extremely diverse group of students who vary among many factors, including (but not limited to) race, family and schooling backgrounds, immigration circumstances, generational status, languages they know and speak, English language proficiency, and the types of programmatic supports they might be receiving (or have received) in school to address their English language development (e.g., sheltered English instruction, pull-out programs, ESL programs, bilingual classroom aids, etc.). Most importantly, EMLs bring into our classrooms multiple resources as well as rich lived experiences and ideas about how our natural world works. As EMLs are a student group that has historically received unequal access and inadequate instruction in science, it is critical that teachers learn to notice, value, and leverage their EMLs' contributions in the classroom. Doing so will only enrich the classroom community's science learning experiences.

### Why is it important to focus on EMLs when considering the instructional shifts called for by the Next Generation Science Standards (NGSS)?

The vision set forth by the NGSS calls for major shifts in the teaching and learning of science, in which students learn in the context of puzzling phenomena and engage in authentic science and engineering practices (SEPs) as they seek to make meaning of these phenomena. The emphasis on SEPs builds on prior reforms that used the concept of "inquiry" to highlight that students should actively generate knowledge. However, previous conceptions of what "inquiry" in science meant ranged greatly, from carrying out investigations to engaging in "hands-on" experiences (another catch-all phrase used in science education). Adding specificity to what inquiry entails, SEPs more clearly articulate the ways students ought to collaborate with peers to develop understandings of natural phenomena or to solve design problems. To meaningfully engage in these SEPs, students must use language in increasingly complex ways. For example, students are now expected to *construct explanations* and *engage in argumentation from evidence*, both of which require the use of various linguistic (e.g., speaking and writing) and nonlinguistic (e.g., drawings, graphs, models, gestures) forms of communication. Adding to this complexity, this language use occurs in real time as students take in their peers' ideas, make sense of them in light of their own thinking, and respond in ways to further the group's understanding of the topic being explored. These language demands present opportunities for EMLs to tap into their language resources and assets but could also bring about potential challenges if certain English language needs go unaddressed.

### How is language used for scientific sensemaking?

A major function of language is to provide a way for us to make sense of the world and to share that sensemaking with others. In science, we make sense of phenomena using both linguistic and nonlinguistic forms of communication, which provides learners of science with many different ways to access new content and share how they are making sense of these phenomena. When considering what these language demands mean for EMLs, the tendency has been to focus on students' English language development first, believing a certain threshold of English is needed to learn and do science. This perspective has led to inequitable science learning opportunities for EMLs, with these students being removed or kept from certain experiences until reaching particular English proficiency levels. However, extensive research into how we can support the science learning of EMLs shows that science learning and language development mirror and support one another and should not be viewed as two separate processes. An example of a common instructional practice that does not integrate language and science has been to focus on pre-teaching vocabulary at the start of a science unit. Instead, research shows that teachers should provide students with authentic contexts through which to explore science ideas and "earn" new vocabulary as they develop their own understandings of science concepts and processes. (See the Developing Scientific Language section of for details.)

Phenomenon-driven science instruction provides EMLs with authentic contexts and purposes for which to use their developing language(s) and supports students in making sense of the phenomenon being explored. Moreover, as the content students learn becomes more sophisticated, so do the ways students end up using language to make sense of it. It is of utmost importance that teachers deeply understand the ways language is used for scientific

sensemaking to ensure that all students, particularly EMLs, have equitable learning experiences in the science classroom. Understanding the role of language in sensemaking includes valuing the assets EMLs have as well as knowing forms and features unique to each SEP. For example, when engaging in the practice of argumentation, students generate arguments in the structural form of a claim substantiated with evidence and reasoning (e.g., CER statements). Additionally, it is important for teachers to identify and attend to the challenges EMLs might encounter when engaged in reform-oriented science instruction based in science practices. EMLs have many meaning-making resources, which teachers can learn to see and acknowledge in their classrooms. Focusing on these assets can allow teachers to leverage students' prior conceptions and knowledge about science concepts being covered. This helps make learning experiences more meaningful to EMLs, positioning them as valuable contributors to the classroom community's knowledge construction work. Furthermore, thinking about potential challenges that EMLs might face can allow teachers to proactively come up with solutions to better support their students' needs.

### **How does the instructional model support EMLs?**

There are two primary ways that the instruction supports EMLs: (1) through the curricular design and pedagogical routines that are at the heart of its instructional model, and (2) through educative boxes embedded in the teacher materials. The curricular design and routines ground students' learning experiences in real-world phenomena. For instance, a sixth grade unit on thermal energy is anchored in students figuring out, *How can containers keep stuff from warming up or cooling down?* In this approach to science learning, students are not just memorizing science ideas or "facts" about energy transfer but instead are working with peers to figure out their own understanding of—and even design their own solutions for—real problems that occur in our natural world. When the phenomena being explored are relevant and accessible, EMLs are better able to contribute and build from their previous understandings about the phenomena. As mentioned earlier, engaging in phenomena-driven science instruction also simultaneously supports EMLs' science learning and language development. Furthermore, the various pedagogical routines embedded in the instructional model—including the Anchoring Phenomenon routine, Investigation routine, Problematizing routine, and Putting Pieces Together routine—encourage EMLs to use their multiple meaning-making resources and provide students with numerous opportunities to make their ideas public through both linguistic and nonlinguistic modes of communication. The teacher materials also include educative boxes focused on EMLs, often appearing as supplemental text in the margins of lesson plans. These educative boxes support teachers in considering whether particular learning moments might be spaces where they can leverage their EMLs' assets and/or address potential challenges their students might encounter. These educative boxes help teachers provide additional in-time support and explain why these instructional moves are important for EMLs. They also range greatly, from suggesting particular ways to group students to unpacking the meaning of certain words in the context of science.

## L. Assessment System

The assessment system is grounded in the recommendations of the National Research Council (2014) report *Developing Assessments for the Next Generation Science Standards*. An assessment system is a holistic way of supporting teacher autonomy and offers multiple ways for students to demonstrate their ability to reason with the three dimensions. The system has assessments embedded in the unit, options for self- and peer assessment, and multicomponent tasks. The report recommends the use of multicomponent tasks as a centerpiece for assessment—that is, tasks that are organized around a scenario presented to students that tests their ability to apply understandings of core ideas and crosscutting concepts to explain a phenomenon or solve a problem using science and engineering practices.

### Types of Assessments

Each unit includes an assessment system that offers many opportunities for different types of assessments that work together to help teachers inform instruction throughout the lessons. The types of assessments that can be found are as follows:

- **Pre-assessment:** Pre-assessment opportunities are found in early lessons in the units, usually in the form of initial models and DQB questions. The goals of pre-assessments are (1) to give teachers evidence of what ideas and practice competencies students are coming into the unit with and (2) to get a diverse set of ideas on the table that teachers can leverage throughout the unit to support argumentation and sensemaking. Many embedded instructional activities can be used as pre-assessments, including initial models, driving questions for the DQB, and discussions around early class consensus models.
- **Formative assessment:** Formative assessments are meant to guide and advance learning through providing information that helps teachers learn about their students, strengths and weaknesses and make subsequent instructional decisions. Formative assessment opportunities are built into the unit and are meant to be points along the way where teachers can see where students are as they build understanding. In three-dimensional science instruction, this often means that formative assessment happens as students are still working on building their understanding across the units and will often assess incomplete pieces of the final understanding. Look for formative assessment opportunities for each lesson performance expectation in the Lesson-by-Lesson Assessment table.
- **Self-assessment:** Self-assessments are opportunities for students to learn and grow from their participation in the class learning community. Teachers can decide where in the unit they would like to help students reflect on their growth. In addition, specific opportunities in the unit are identified where teachers can have their students self-assess their own progress by using more generic tools that help teachers facilitate student self-assessment. For example, the discussions rubric helps students understand and apply criteria for large-and small-group classroom communication.
- **Peer assessment:** There will be times in classrooms when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback to and from others. It is suggested that peer review happen at least two times per unit. The Peer Feedback Facilitation document (found in the appendix) is designed to give options for how to support this type of assessment in classrooms. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process.
- **Summative assessment:** Summative assessment opportunities are built into the unit and can occur at the end of each lesson set or the end of the unit. The purpose of summative assessment is to obtain evidence of what students have learned to (1) provide them with information on where they are in their learning (compared to where they need to be) and (2) provide teachers with information to adjust future instruction and usually assign a grade. Summative assessments can be transfer tasks in which students are asked to make sense of a new phenomenon, or they can be final models, arguments, or explanations of the phenomenon explored in the class. Either way, summative assessments should be closely linked to the targeted performance expectations and directly address concepts and practices that the unit focuses on developing and using.

Each unit has identified these key moments of assessment and has included them, along with assessment and scoring guidance, in the Assessment Overview Table at the beginning of each Teacher Guide and within the keys and rubrics associated with lessons.

## Formative Assessments and Lesson-Level Performance Expectations (LLPEs)

A lesson-level performance expectation (LLPE) is a three-dimensional learning statement for each lesson, aimed at highlighting the key student expectations for that lesson. Every lesson includes one or more LLPEs. The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas, and crosscutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to **science and engineering practices**, alignment to **crosscutting concepts**, and alignment to the **disciplinary core ideas**.

Each unit includes a table that summarizes opportunities in each lesson for assessing every LLPE. Examples of these opportunities include student handouts, home learning assignments, progress trackers, and student discussions. Most LLPEs are recommended as *potential* formative assessments. Assessing every LLPE listed for each student can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion. However, the system is designed to support a quick review of the LLPE, assessment guidance, and a subset of student work to help inform instructional decisions throughout the unit even if you are not assessing each student individually every time.

## Progress Trackers

The Progress Tracker is a formative and self-assessment tool that is designed to help students keep track of important discoveries that the class makes while investigating the phenomenon and to help them figure out how to prioritize and use those discoveries to focus on explaining the phenomenon they're working on. Students will refer back to the tracker regularly to revise or build on their models, explanations, and/or designs for their current thinking about the phenomenon. Furthermore, students, and the class as a whole, will use the tracker as a way to think with others about what is important in their models, explanations, and/or designs.

It is important to note that this tool is designed to be a dynamic resource that students can use to progressively make sense of their ideas. It is suggested that teachers use this tool to support progressive sensemaking throughout the unit and avoid using this tool as a simple note-taking activity. In the teacher guidance for each lesson that uses Progress Trackers, suggestions are given for supporting students in using the tracker to identify discoveries and use those discoveries to continually revisit, revise, and prioritize ideas. In order to avoid Progress Tracker fatigue, teachers should not have students use the tracker every day in the same way but rather have them use it to further the sensemaking when applicable.

There are two structures that teachers can use during any unit. The choice provides teachers with flexibility to customize for their local context.

1. The two-column Progress Tracker in a science notebook that includes only the "Question" and "What I Figured Out" columns
  - a. In the "What I Figured Out" column, students can draw pictures or write in words, bullet points, or whatever way is most meaningful for that individual. By having no structured box, students can take up a lot of space or a little space. Whenever a student is done, they can draw a line after their work to make space for the next time the teacher instructs them to write in their tracker.
  - b. If a teacher decides that the class needs a break from using the tracker, the class simply doesn't fill it out, and the next question will appear directly below (no blank rows would appear in the students' trackers).
2. The three-column Progress Tracker that includes columns for "Question," "Source of Evidence," and "What We Figured Out / Representation of Our Ideas"
  - a. Students work on this row after important punchlines in the unit are figured out as a class, usually after the class came to consensus about an idea or set of ideas. However, it occurs more than only when the Putting Pieces Together routine is used.
  - b. We do not suggest skipping this Progress Tracker move in the unit. If these pieces are missing, students may have trouble moving forward in their sensemaking.

- c. One point at which students can fill these out is during the Navigation routine on the next day after the class comes to consensus on something. This avoids the redundancy of coming to consensus and directly recording individually what the class figured out. It can also help reinforce using the Progress Tracker as a tool for formative and/or self-assessment.

Example of both forms of the Progress Tracker:

*Our Driving Question: How does stuff inside our bodies make us feel the way we do?*

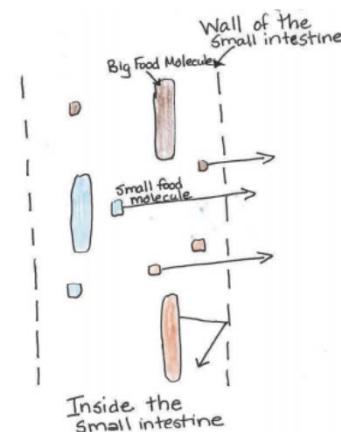
Question	What I Figured Out
1. What's going on with M'Kenna's body that is making her feel the way she does?	Her symptoms seem to be coming from lots of different parts of her body!  Some of the symptoms started first and then others started to come later.  I don't really know what's going on, but I have a lot of questions!
2. Can we see anything inside of M'Kenna that looks different?	MK's small intestine is really smooth compared to a healthy person's small intestine.  Is her small intestine causing the problem?

Question	Source of Evidence
3. Could food molecules be getting absorbed through the surface of the small intestine?	Dialysis bag experiment  Molecular models of starch (big carbohydrate) vs. sugar/glucose (small carbohydrate)

### What We Figured Out in Words/Pictures

Dialysis tubing is kind of like our small intestine—it's a big tube with holes.

When we put big food molecules like starch in the dialysis tubes, they are too big to fit through the holes, but smaller food molecules like glucose can fit through. We knew this because the color changed on the outside—detecting the small food molecules but not the big ones.



In the example trackers, each of the rows and columns has been completed with *possible* student ideas. This tracker serves as teacher guidance for what students may say at various points throughout the unit. Some students may say more, and others may say less. It is important that what the students write in the two-column tracker reflects their own thinking at that particular moment in time. When the three-column tracker is filled out after a consensus moment in the unit, those rows will look more similar between students. In this way, the tracker can be used to formatively assess both individual student progress throughout the unit and progress as a class. Because the tracker is meant to be a thinking tool for students, we strongly suggest it not be collected for a summative “grade” other than for completion. This is to avoid undermining the freedom for students to put their current understanding and questions about their developing ideas without concern for being “right” or “wrong.”

## Assessment Rubrics

Assessments, along with guidance for their use, are included with each unit. However, there are general assessment rubrics that are integrated across more than one unit. Examples include the following:

- Self-assessment for discussion
- Peer feedback guidelines
- Modeling rubric
- Argumentation rubric

These resources are found within each unit that uses them.

## M. Supporting English Language Arts (ELA)

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The goal of integrating English language arts within units is to use literacy practices of reading, writing, and communication to develop and reinforce important science ideas and practices while supporting students in strengthening their English language arts practices and demonstrating the importance of language practices for science.

### Use of Text

The units are intentional in their placement and purpose of text. Text is placed within the unit at key junctures where students need to gather information to motivate the storyline, better understand a concept, or work through an investigation. Generally, students experience a concept in some way prior to reading about it, allowing them to make a connection between their experience of a concept and scientific information in the text. Text that introduces a phenomenon to students is adapted for classroom use and intended to engage students in the storyline (for example, a doctor's note, an abstract and methodology section from a study, or field observations). Some text is just-in-time to help the storyline along, to generate questions or ideas from students, to help to clarify some piece of the puzzle students are figuring out, or to give students language to describe what they are seeing. Texts are also used to extend learning or satisfy student curiosity related to the phenomenon. Current and future texts will feature people of different ages, genders, cultures, abilities, and racial and ethnic groups engaged in the scientific enterprise and will include individuals with different perspectives, working toward similar or different purposes, as part of different disciplines and communities (such as citizen scientists, families, or classmates).

Students analyze texts using strategies drawn from Common Core State Standards, and these connections are outlined at the end of each lesson. Lessons are designed to have students cite specific textual evidence to support analysis of science and technical texts; determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions; follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; 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; analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic; analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text; integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (such as a flowchart, diagram, model, graph, or table); distinguish among facts, reasoned judgment based on research findings, and speculation in a text; and compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on the same topic.

The units include several strategies for text analysis. One strategy, a **close reading strategy**, is used throughout the units as a common approach for students to engage with text. The steps in the strategy are as follows:

1. Identify the question(s) you are trying to answer in the reading.
2. Read once for understanding to see what the reading is about.
3. Read a second time to highlight a few key ideas that help answer the question(s) you had.
4. Summarize the key idea(s) in your own words, in diagrams, or both.
5. Jot down new questions that this raises for you.

#### **Example directions found in the Learning Plan of a lesson:**

**Model the close reading strategies.** Project **slide C**. Describe that close reading requires reading more than once and with different purposes and strategies for interacting with the text. Go through the following steps, which are on the slides, with students:

1. Project **slide D**. Say, "Let's do one together." Ask students what the main question in this reading is that we are trying to answer. Tell students to circle the *What is air?* question at the top as a key strategy because it reminds us what the purpose is of what we are trying to do and what type of information we are looking for in the reading.

Have students write down this question at the top of the reading: **What is in the air?**

2. Project **slide E**. Give students time to read the first two paragraphs of the reading on their own.
3. Project **slide F**. Show students an example of step 3 by rereading aloud the first section. As you read, pause and share your thinking, highlighting a few ideas that answer the focus question.
4. Project **slide G**. Tell students they are going to try steps 4 and 5 by adding the summary of key ideas and new questions they have to their Progress Trackers. Project **slide H**. Tell students to fill in a row of their Progress Trackers with what they just figured out.

## **Emphasis on Communication**

Students are frequently engaged in speaking, listening, and responding to others as part of their participation in science and engineering practices. The units provide guidance and rubrics aligned to Common Core State Standards for speaking and listening, including standards for comprehension, collaboration, and presentation of knowledge and ideas. Students frequently engage in peer-to-peer discussion to share, express, and refine their thinking based on new information. They develop, present, and defend their ideas to one another, verbally, in written forms, and in expressive forms in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details. See appendix for resources on discussion and peer feedback.

## **Writing in Science**

The units are intentional about the purpose, placement, and variety of written work. Units incorporate a student science notebook and additional written student work on a daily basis for students to write, draw, and communicate their understanding of science ideas and practices. Written work integrates standards for writing from the Common Core State Standards, and instructional materials ask students to articulate claims and arguments, cite evidence from their own work and scientific sources, and evaluate the claims and counterclaims of others. Students draw upon a variety of texts and analyze graphs, tables, and images as part of writing development. These connections are noted at the end of each lesson.

## Science Notebook Management

### Purpose of the Science Notebook

The science notebook creates a space for students to record investigations and communicate their ideas about phenomena. The notebook is also a record of how students' ideas evolve over time. Developing a science notebook can create a sense of ownership for students with respect to their intellectual work in the classroom. It can also be a valuable formative assessment tool for teachers.

### Tips for Setting Up the Notebook and Organizing the Work

*What type of notebook should we use?* Composition notebooks are inexpensive and easy for classroom and backpack storage. The downside of using composition notebooks is the reduced page size, where students may run out of room as they record their work. Spiral notebooks afford more space on the page but can be problematic for storage. Either is fine for use as a science notebook in your classroom. Handouts can be taped or glued into the science notebook, and they may be folded in half to fit on the page.

*How can I help students organize their notebooks?* The level of organization you want students to use with science notebooks will depend on your teaching style and the goals for notebook use in your classroom. The organization can range from highly structured and sequential to random. If the notebooks are too random, students may struggle to locate their work and to track their developing understandings. Some organization, particularly early in students' use of the science notebook, can be useful so that students develop a vision for what to record and how to record it:

- **Page numbers:** One suggestion for organization is to use page numbers. Have students number the pages at the start of the year or the start of a unit (e.g., the first 50 pages or so). Then ask students to record their work on a specific page number that the whole class can reference at a later date (e.g., "Let's look at the model we drew for X on page 35").
- **Table of contents:** Another organizational tool is a table of contents. This can give students flexibility to record their own page numbers that correspond with different activities. If you choose to use a table of contents, make sure to offer time at the end of class for students to update their tables of contents.

*What do students include in a notebook entry?* Students should title the notebook entry for easy reference later. Additionally, students can write the lesson or investigation question near the top of the page to remind them of the purpose of the investigation and what they are trying to figure out. Students may also date their work.

### Tips for Using the Notebook Effectively

What is recorded in a science notebook? Anything can be recorded in the science notebook, but you will see the following kinds of activities used throughout this curriculum:

- Recording student thinking (e.g., Notice and Wonder charts, initial ideas and questions, explanations)

Observations of Materials

How do the best designs and materials differ from the worst designs and materials?

Best Performers	
Notice	Wonder
You can squeeze them. They're soft. They look like they have holes or bubbles in them with air.	Why are there bubbles? How do the bubbles help?
Pattern: Air Pockets	
Worst Performers	
Notice	Wonder
They're hard and you can't squeeze them. They look smooth with no air bubbles.	Why are they hard? Does "hardness" cause them to warm up?
Pattern: Solid, hard no air	

Touching Hot and Cold

**HOT**

**COLD**



## Developing Scientific Language

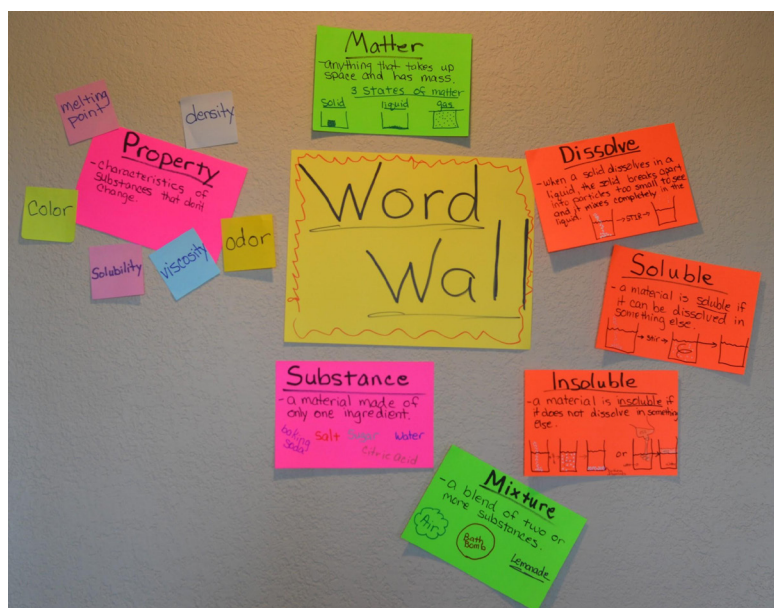
Some instructional approaches emphasize the role of introducing key vocabulary before learning about the concepts they are connected to in a lesson. That is *not* an approach we support in units. While we agree that developing scientific terminology is one important goal for students, it should not undermine the heavy lifting we want students to engage in intellectually. In each lesson, we want students engaging in practices around a question that they feel a genuine need or drive to figure out. Front-loading vocabulary hinders this process and also puts up barriers against emergent multilingual students engaging in class discussions.

Students can communicate about and grapple with phenomena without using scientific terms. Once *all* students have developed a conceptual understanding of an idea in a lesson, introducing a relevant scientific term as a shorthand way to reference that idea makes complete sense. It is simply a matter of timing and where we want them focusing their intellectual work.

Here is an example: In a unit on sound, students notice that the graph of the vibrations produced by an object exhibits two interesting characteristics. A few rounds of trying to describe patterns (first individually, then with a partner, and finally as a whole group) lead students to start talking about two features of these patterns that can be compared and measured. One feature can be described in terms of the distance from the y-value of a high point on the graph. The other can be described in terms how often that pattern repeats. It is at this point, after the class has worked with these ideas for a bit and wrestled with what words best describe each feature, that the teacher can point out that it seems cumbersome to keep referring to these features to describe the graphs and that two terms are used to refer to these features. One is *amplitude*, and one is *frequency*. At this point, it makes sense to consolidate students' ideas by showing how these two terms correspond to the patterns they observed and were describing. From this point on, using these terms to represent these features of such graphs is meaningful and appropriate.

This approach to vocabulary building doesn't undermine the sensemaking of students or defeat the goal of figuring out important science ideas in each lesson. We want to give students a rich opportunity and experience to wrestle with developing these important science ideas before introducing vocabulary to represent an abbreviated description of those ideas.

As new scientific terminology is developed with the class, we recommend that you build a word wall (example shown here) of these ideas. Keeping a visual model, or examples if applicable, next to each word can help students recall the concept the word is associated with.



## N. Supporting Mathematics

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The goal of integrating mathematics within units is to use mathematical understanding and practices to develop and reinforce important science ideas and practices while supporting students in strengthening their math understanding and practices and demonstrating the importance of mathematical thinking and practices to science.

The units are intentional in their placement and purpose of mathematics. Mathematics is intended to help the storyline along, to help clarify some piece of the puzzle students are figuring out, or to give students tools to highlight, analyze, and interpret important patterns in the data they are exploring. When applying mathematics, materials connect to and reinforce the Common Core State Standards for mathematics. Mathematical analysis is not used in isolation from developing understanding of the target science ideas. Connections to mathematics are noted at the end of each lesson where appropriate.

The units integrate mathematical understanding and practices that are grade-level appropriate across both math and science standards. They align to the development of the mathematical topics in the Common Core State Standards for mathematics and do not require or attempt to teach them before they have been addressed in the Common Core. For example, statistical measures of center are not introduced until grade 6, and probability is not addressed until grade 7. Guidance on mathematical knowledge and practices is provided in the Teacher Background Knowledge for each unit to indicate alignment to the Common Core and to alert teachers of opportunities to attend to the connections.

Where appropriate, the units provide support and modifications for students with special learning needs related to mathematics. For example, they may provide alternate student prompts to provide opportunities for students to engage with mathematics qualitatively rather than quantitatively. Instructional materials embed scaffolds to help students break down the use of mathematics into manageable parts and use multiple representations and manipulatives of mathematics concepts to help reinforce mathematical concepts or reasoning. Where possible, teacher materials provide support to break down analysis of the data into smaller steps or explain the problem in a different way.

## O. Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstrations, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., safety goggles, non-latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults, and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the units includes teacher guidelines for applicable safety procedures for setting up and running an investigation as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgment form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgment form for middle school activities at the following location: <http://static.nsta.org/pdfs/SafetyAcknowledgmentForm-MiddleSchool.pdf>

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

### **Please follow these lab safety recommendations for any lesson with an investigation:**

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non-latex apron, and non-latex gloves during the setup, hands-on investigation, and takedown segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip-and-fall hazard.
3. Follow your Teacher Guide for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing the activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.



Specific safety precautions are called out within the lessons using this icon and a callout box.

# Appendix

## Self-Evaluation: Engaging in Classroom Discourse

Setting	Criteria	Absent I do not do this	Developing I occasionally do this (sometimes)	Proficient I often do this	Mastery I consistently do this
In large/whole-group settings (Scientists Circle discussions, gallery walks, etc)	<b>Shares one's own thinking</b> by contributing new ideas, questions, and additional clarification				
	<b>Listens actively to others,</b> rephrasing, repeating, and/or reusing the ideas others have shared and asking others to repeat their statements or to clarify ideas when they are difficult to hear or understand				
	<b>Respectfully provides and receives critiques</b> about explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions				
	<b>Invites others to share</b> their thinking and contribute their ideas				
Setting	Criteria	Absent I do not do this	Developing I occasionally do this (sometimes)	Proficient I often do this	Mastery I consistently do this
In small-group settings (partner talk, small-group discussions, lab work)	<b>Shares one's own thinking</b> by contributing new ideas, questions, and additional clarification				
	<b>Listens actively to others,</b> rephrasing, repeating, and/or reusing the ideas others have shared and asking others to repeat their statements or to clarify ideas when they are difficult to hear or understand				
	<b>Respectfully provides and receives critiques</b> about explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions				
	<b>Invites others to share</b> their thinking and contribute their ideas				

*These materials were developed with funding through grants from the National Science Foundation, the Gordon and Betty Moore Foundation, Denver Public Schools to Northwestern University and the University of Colorado Boulder.*

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# Peer Feedback Facilitation: A Guide

*With Student Guidelines and Rubrics*

## Teacher Instructions

There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least once, but preferably two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process.

### When is a good time to facilitate peer review?

Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work; rather, peer feedback will be more valuable to students if they have time to revise after receiving the feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

### What are classroom structures I can use for peer review?

Below are three examples of ways to organize peer review in your classroom. You may choose to use all of them depending on your time or material constraints, or you may choose to always use one structure for review so that your students get familiar with it and become better at it over time.

**Sticky Note Peer Review:** In this protocol, shared on Tools for Ambitious Science Teaching, students use sticky notes to leave questions and comments on posted student work. There is time built in for students to respond to feedback. Use the self-assessment rubrics in this document at the end of the class period for students to reflect on their experience in this feedback session.

**Peer Review with Unit Rubrics:** All units and the curriculum overall have science and engineering practice (SEP)–specific rubrics for teachers to assess student work. You can also use these as a way for students to assess each other’s work and give feedback on how to improve. We suggest having students use the rubrics to give specific feedback to each other. You can use these in a gallery walk–type setting or have students exchange models.

**Group Review:** Ask students to get into groups of four. Have the students bring their individual model or explanation (or other piece of student work) to the group. Review feedback guidelines as a class, giving examples of good and bad feedback. Then, in pairs, have students provide feedback to the other two pieces of student work. They can use sticky notes or write directly on the work. Make sure to leave individual work time for students to revise their models and complete the self-assessment rubric.

## Giving Feedback to Peers

This tool was developed with ideas from the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at <https://ambitioussciencelearning.org/sticky-note-student-feedback/>.

### Feedback needs to be specific and actionable.

That means it needs to be related to science ideas and provide your own suggestion for improvement.

Productive examples:

- “Your model shows that the sound source changes position when it is hit. I think you should add detail about how the sound source moves back and forth after it is hit.”
- “You said that the drum moves when it makes sound but the table doesn’t move when it makes sound. We disagree and suggest reviewing the observation data from the laser investigation.”

Nonproductive examples of feedback that do not help other students improve:

- "I like your drawing."
- "Your poster is really pretty."
- "I agree with everything you said."

### How to Give Feedback

Your feedback should give ideas for specific changes or additions the person or group can make. Use the sentence starters below if you need help writing feedback.

- The poster said \_\_\_\_\_. We disagree because \_\_\_\_\_. We think you should change \_\_\_\_\_.
- I like how you \_\_\_\_\_. It would be more complete if you added \_\_\_\_\_.
- We agree that \_\_\_\_\_. We think you should add more evidence from the \_\_\_\_\_ investigation.
- We agree/disagree with your claim that \_\_\_\_\_. However we do not think the \_\_\_\_\_ (evidence) you used matches your claim.

### Receiving Feedback from Peers

The purpose of feedback is to get ideas from your peers about things you might improve or change to make your work more clear, more accurate, or better supported by evidence you have collected or to communicate your ideas more effectively to others.

When you receive feedback, you should

- read it carefully, asking someone else to help you understand it if needed;
- decide if you agree or disagree with the feedback and say why you agree or disagree; and
- revise your work to address the feedback.

## Self-Assessment: Giving Feedback

How well did you give feedback today?

Today, I...	Yes	No
Gave feedback that was <b>specific</b> and about <b>science ideas</b>		
<b>Shared a suggestion</b> to help improve my peer's work		
<b>Used evidence from</b> investigations, observations, activities, or readings to support the feedback or suggestions I gave		

One thing I can do better next time when I give feedback is:

## Self-Assessment: Receiving Feedback

How well did you receive feedback today?

Today, I...	Yes	No
<b>Read the feedback</b> I received carefully		
<b>Asked follow-up questions</b> to better understand the feedback I received		
<b>Said or wrote why I agreed or disagreed</b> with the feedback		
<b>Revised</b> my work based on the feedback		

What is one piece of feedback you received?

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What did you add or change to address this feedback?

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### Example Modeling Rubric from Sound

Components	Category			Feedback
	Missing	Developing	Mastered	
Clearly represents or describes the system components and must include:				
• The <b>sound source</b>				
• The <b>initial force applied</b> to the sound source				
• The <b>particles of the medium</b> (air) in between the sound source and detector				
• The <b>detector</b> of the sound.				
Interactions between Components	Category			Feedback
Clearly represents or describes the following:	Missing	Developing	Mastered	
• That the deformation of the sound source causes the particles in the medium to start moving ( <i>cause/effect</i> )				
• That particles in the medium go back and forth and hit neighbors (show this with some sort of convention for wiggle) ( <i>cause/effect</i> ) but do not move all the way from the source to the detector				
• The repeated nature of this back-and-forth motion of the shape of the sound source (may identify this back and forth motion as a vibration) ( <i>pattern/structure</i> )				
• That the particles of the medium push on the “detector,” causing it to move ( <i>cause/effect</i> )				
• That collisions transfer energy across the medium (the energy moves from the sound source to the detector, but the particles do not move all the way from the sound source to the detector) ( <i>energy</i> )				
• That particles and the sound source go back to their original starting position ( <i>pattern/structure</i> )				

## Argument Rubric from *Inside Our Bodies*

Claim	Category			Feedback
	Missing	Developing	Mastered	
<ul style="list-style-type: none"> <li>• <b>There is a claim</b> that states that M’Kenna has celiac disease.</li> </ul>				
Justification Evidence or empirical data that supports the claim includes:	Category			Feedback
	Missing	Developing	Mastered	
<ul style="list-style-type: none"> <li>• M’Kenna’s endoscopy images of her small intestine look different from the healthy small intestine images.</li> </ul>				
<ul style="list-style-type: none"> <li>• Graphs show that M’Kenna is breaking down all large food molecules except for all “other complex carbohydrates.”</li> </ul>				
<ul style="list-style-type: none"> <li>• Graphs show M’Kenna has food molecules left in her large intestine and poop that are not found in a healthy person.</li> </ul>				
<ul style="list-style-type: none"> <li>• M’Kenna has flat villi in her small intestine.</li> </ul>				
Scientific principles or ideas that explain how each piece of evidence supports the claim ( <i>reasoning</i> ) include:				
<ul style="list-style-type: none"> <li>• Since there are structural differences in the small intestine images, this indicates there could be a difference in the function of M’Kenna’s small intestine.</li> </ul>				
<ul style="list-style-type: none"> <li>• Since small molecules are not being absorbed by the small intestine, they continue moving down her digestive tract and end up in her poop.</li> </ul>				
<ul style="list-style-type: none"> <li>• The food molecules are being broken down in M’Kenna and in a healthy person because we see large food molecules in the graphs go down and small food molecules go up, but then in M’Kenna, they are not all being absorbed because food molecules are still left in her poop and large intestine.</li> </ul>				
<ul style="list-style-type: none"> <li>• Flat villi make it more difficult to absorb food, so small molecules are left over in the process as food moves through the body. The villi are the cells of the digestive system in the small intestine where food is absorbed. When functioning properly, villi increase the surface area in the small intestine where small food molecules can be absorbed (<i>structure/function</i>).</li> </ul>				

<b>Rebuttal</b> Clearly represents or describes the following:	<b>Category</b>			<b>Feedback</b>
	Missing	Developing	Mastered	
<ul style="list-style-type: none"> <li>• A critique of the evidence of an alternate claim               <ul style="list-style-type: none"> <li>○ Not other diseases because the damage is located in the small intestine</li> <li>○ The other small intestine diseases are not caused by damage to the villi structures.</li> <li>○ Any other valid critique that relies on evidence</li> </ul> </li> </ul>				
<ul style="list-style-type: none"> <li>• A critique of the reasoning of an alternate claim               <ul style="list-style-type: none"> <li>○ The disease M’Kenna has must be related to the small intestine because that is where we knew there was damage from the images we examined.</li> <li>○ The disease M’Kenna has must be a result of or related to the damage of villi in the small intestine because we know that the damaged villi, absorb small molecules less efficiently than normal villi, which can explain why we see small molecules in M’Kenna’s poop.</li> <li>○ Any other valid critique of reasoning that students propose</li> </ul> </li> </ul>				

## Acknowledgments

This content compiled by OpenSciEd that is republished in this handbook represents a synthesis of ideas, strategies, and resources developed across the science education community. These resources include:

Sections A, C, and D were adapted from the NextGen Science Storylines at Northwestern University and from the Next Generation Science Exemplar System Project (NGSX) at Clark University and Tidemark Institute and draw on the work of the Investigating and Questioning Our World through Science and Technology Project at the University of Michigan, Northwestern University, and Michigan State University. NextGen Science Storylines was funded by the Gordon and Betty Moore Foundation, the James S. McDonnell Foundation, and the Carnegie Corporation of NY to Northwestern University; the William and Flora Hewlett Foundation to the University of Colorado Boulder; and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University. The Investigating and Questioning Our World through Science and Technology Project was funded by National Science Foundation grants ESI-0439352 and ESI-0439493 to the University of Michigan and Northwestern University. The opinions expressed herein are those of the authors and not necessarily those of the NSF.

Portions of Section F draw from ideas in the STEM Teaching Tool #41 developed by the Institute for Science + Math Education at the University of Washington. The full tool is available at <http://stemteachingtools.org/brief/41>.

Section H draws directly from the work of: CAST. (2018). *Universal Design for Learning Guidelines version 2.2*. Retrieved from <http://udlguidelines.cast.org> and portions related to differentiation were developed with ideas from Tomlinson, C. A., & Allan, S. D. (2000). *Leadership for differentiating schools and classrooms*. Alexandria, VA: ASCD.

Portions of Section I draw from the work of the Science Education Research Partnership (SERP) and the Next Generation Science Exemplar Project (NGSX). Two specific resources are Michaels, S., & O'Connor, C. (2014). *Establishing norms: Laying the foundations for academically productive talk* and O'Connor, C., Ruegg, E., & Cassell, C. (2017). *Establishing classroom discussion norms*.

Portions of Section J were adapted from from tools and processes developed by NextGen Science Storylines at Northwestern University and from the Next Generation Science Exemplar System Project (NGSX) at Clark University and Tidemark Institute, from Science Teachers Learning from Lesson Analysis (STeLLA<sup>®</sup>) project at BSCS Science Learning, and from the work of the Investigating and Questioning Our World through Science and Technology Project at the University of Michigan, Northwestern University, and Michigan State University. This material is based upon work supported by the National Science Foundation under Award Nos. 0310721, 0918277, 0957996, 1118643, 1220635, 1321242, 1503280, 1725389, and 1813127. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

The Peer Feedback Guidelines and Tool were developed with ideas from the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at: <https://ambitiousscienceteaching.org/sticky-note-student-feedback/>

The Self-Evaluation: Engaging in Classroom Discourse Tool was developed with funding through grants from the National Science Foundation, the Gordon and Betty Moore Foundation, and Denver Public Schools to Northwestern University and the University of Colorado Boulder.

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