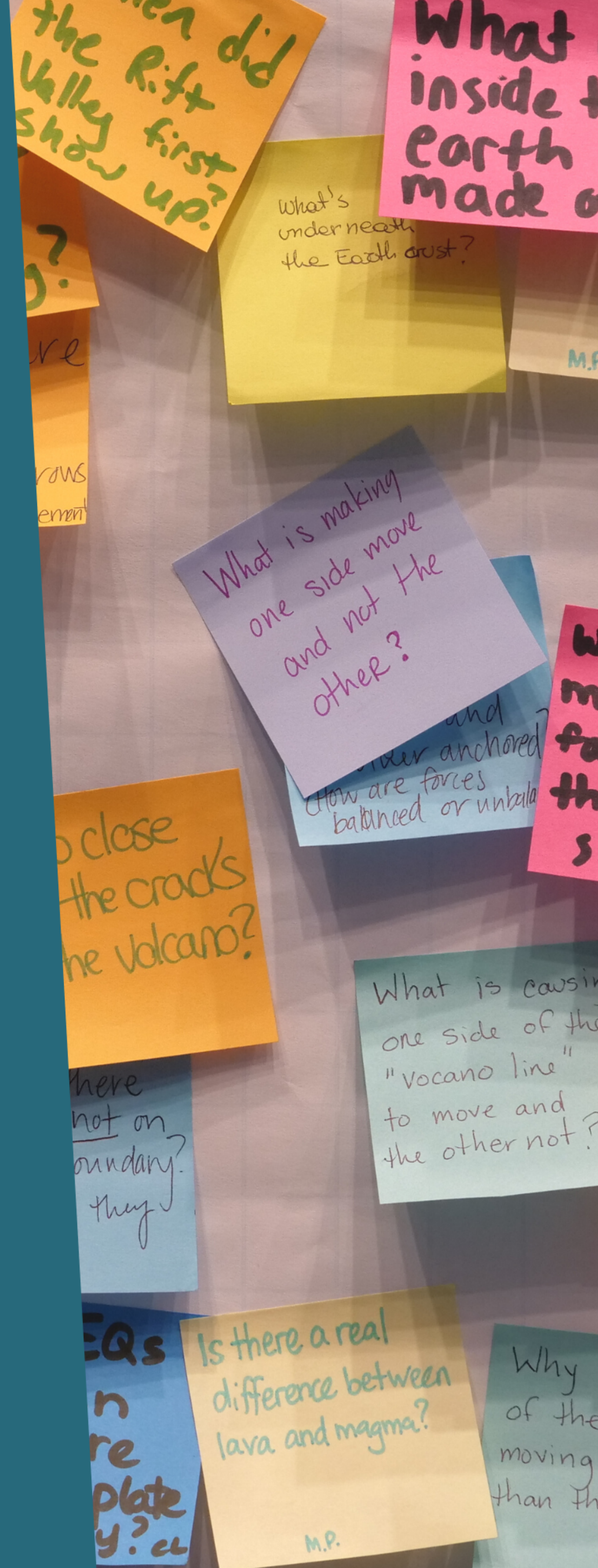
Version 1.0

Teacher Handbook



OpenSciEd

HIGH SCHOOL SCIENCE

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High School Teacher Handbook

Version 1.0
October 2023

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To download the handouts, slides, and other unit resources, visit OpenSciEd.org and complete the free registration.

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About the OpenSciEd Teacher Handbook

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 who 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 OpenSciEd units are designed to provide teachers who are new to three-dimensional learning with enough support to implement the units successfully, this *OpenSciEd Teacher Handbook: High School Science* provides overviews of features of the OpenSciEd 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 OpenSciEd program nor a tutorial on how to implement the teaching practices of the program. The OpenSciEd developers believe that such resources have limited utility. Ultimately, we believe that teachers learn new practices by doing—through the acts of planning, implementing, reflecting, and replanning. We envision this *Handbook* as one support for that learning-by-doing process, ideally in combination with other informational resources, peers, and experts.

The OpenSciEd Instructional Approach

The Science Storylines Approach

OpenSciEd units are designed to follow a storyline instructional approach. Just as listeners of a story are motivated to see what happens next, students moving through a storyline in their science class are motivated by their desire to explain something they don't understand or to solve a problem that is meaningful for them (Reiser, Novak, & McGill, 2017). This approach requires every lesson and embedded activity to follow logically from what came before, in response to real student questions that arise from interactions with a phenomenon or design problem.

An OpenSciEd unit storyline is designed to first introduce students to something puzzling that can be observed in the real world, eliciting questions and ideas for investigations that the class is motivated to pursue. The subsequent sequence of lessons, organized into lesson sets, are designed to support students as they use science and engineering practices to figure out the science ideas that will help them make progress on their questions. Each new science idea is a piece of the puzzle that students work collaboratively to put together, gradually co-constructing an explanation, model, or designed solution. As students analyze their investigation results, compare their models, and argue about their ideas, they generate new questions that lead to additional lines of inquiry for the storyline to follow.

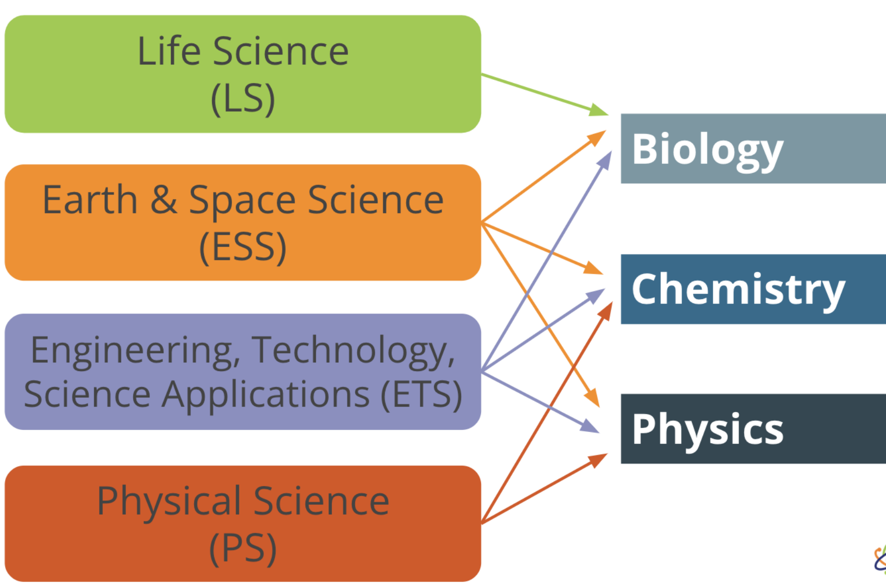
Alignment to the Next Generation Science Standards (NGSS)

The OpenSciEd instructional model is rooted in the recommendations of the National Research Council as laid out in *A Framework for K-12 Science Education* (National Research Council, 2012) and the resulting *Next Generation Science Standards* (NGSS Lead States, 2013). These recommendations include an emphasis on three-dimensional learning that integrates science and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs).

NGSS Dimension	Description
Science and Engineering Practices (SEPs)	Science and Engineering Practices (SEPs) describe: the major practices that scientists use as they investigate and develop models and theories about the natural world; and, the major practices engineers employ as they design, build, and refine systems. The include: 1. Asking questions and defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information For more information see Appendix F of the NGSS

Disciplinary Core Ideas (DCIs)	Disciplinary Core Ideas (DCIs) are a set of core ideas in four science domains: Life Science (LS), Physical Science (PS), Earth and Space Science (ESS), and Engineering, Technology, and Applications of Science (ETS). These core ideas: • have broad importance across multiple science and engineering disciplines or are a key organizing principle of a single discipline; • are a key tool for understanding or investigating complex ideas or solving problems; • relate to student interests and life experiences or connect to societal and personal concerns that require science or engineering knowledge; • and, be teachable and learnable over multiple grades at increasing levels of sophistication. (NRC, 2012, p. 31)
Crosscutting Concepts (CCCs)	Crosscutting concepts provide a useful lens for students as they explain phenomena within a science domain as well as a framework for thinking about science ideas across science domains. The crosscutting concepts include: 1. Patterns 2. Cause and effect 3. Scale, proportion, quantity 4. Systems and system models 5. Energy and matter 6. Structure and function 7. Stability and change For more information see Appendix G of the NGSS

The NGSS organizes these elements into three dimensional assessment targets called performance expectations which are designated as related to one of the four DCI domains: Life Science (LS), Physical Science (PS), Earth and Space Science (ESS), and Engineering, Technology, and the Applications of Science (ETS). The OpenSciEd High School program addresses every performance expectation across these four domains. As illustrated in the graphic below, all the LS standards are addressed in the HS Biology course. All the PS standards are addressed across the High School Chemistry and Physics courses. The ESS standards and the ETS standards are integrated across all three courses. For more detail, see the *OpenSciEd High School Scope and Sequence*.



Each of the three dimensions are further detailed using a set of elements which describe how students engage with the SEPs, what specific science ideas are needed as part of the DCIs, and how to use principles derived from the CCCs to make sense across domains. In each unit, the *Elements of NGSS Dimensions* supplemental material specifies the identification code for each of the SEP, DCI, and CCC elements used in each OpenSciEd High School lesson.

There are several places in the OpenSciEd High School materials where the target elements of the SEPs, DCIs, and CCCs are identified.

- In the *Teacher Guide.* Every lesson contains at least one lesson level performance expectation (LLPE). The LLPE is a three-dimensional learning target describing what students should be able to do and includes the elements listed in parentheses.
- In the *Teacher Guide*. Each teacher guide contains a *Where We Are Going* section describing how students build upon their use of SEPs and CCCs, and knowledge of DCIs. This is followed by a *Where We are Not Going* section that explains why certain ideas are not addressed in particular lessons.
- In the *Teacher Guide.* Callout boxes are embedded within lessons and provide in-the-moment guidance on how to support the use of the three dimensions during instruction.
- In the *Unit Overview.* In each unit, the Unit Overview includes a *Teacher Background Knowledge* section that explains how the three dimensions are incrementally developed and extended through the unit.

OpenSciEd Design Elements

Phenomena Based

In OpenSciEd units, phenomena were purposefully selected to motivate students to figure out and use target disciplinary core ideas, crosscutting concepts, and science and engineering practices. Each unit begins with an ***anchoring phenomenon***, which is used to draw students into the storyline by presenting an interesting, confusing or problematic phenomenon for students to engage with. Other lesson level phenomena may be introduced at key points in a storyline to maintain interest or push students to delve more deeply.

During the development process, an anchoring phenomenon was chosen from a group of candidate phenomena aligned with the target performance expectations based on the results of a survey administered to students across the US and in consultation with external advisory panels including teachers, subject matter experts, and state science administrators. Each course was designed to purposefully highlight different types of relevant phenomena, from everyday experiences like heating food with a microwave, to surprising images like a fire burning under the ice far away, to global injustices like rising sea levels in vulnerable coastal communities. Providing a diverse suite of entry points into science creates more opportunities for every student to connect with the science.

Coherent for Students

A storyline provides a path toward building understandings that are coherent from the students' perspective, and anchored in students' own experiences and questions. For example, when students are presented with an anchoring phenomenon, they ask questions whose answers will help them construct an explanation. Each answered question provides evidence to explain a piece of the phenomenon and leads to more questions. Answering these questions in the order that they arise and building incremental understanding supports coherence from the student perspective. If a visitor were to step into an OpenSciEd classroom on any given day, students would be able to explain not only the piece of the phenomenon they are working on explaining but also how it fits into the bigger picture of what the class has been working on figuring out throughout the unit.

Driven by Evidence

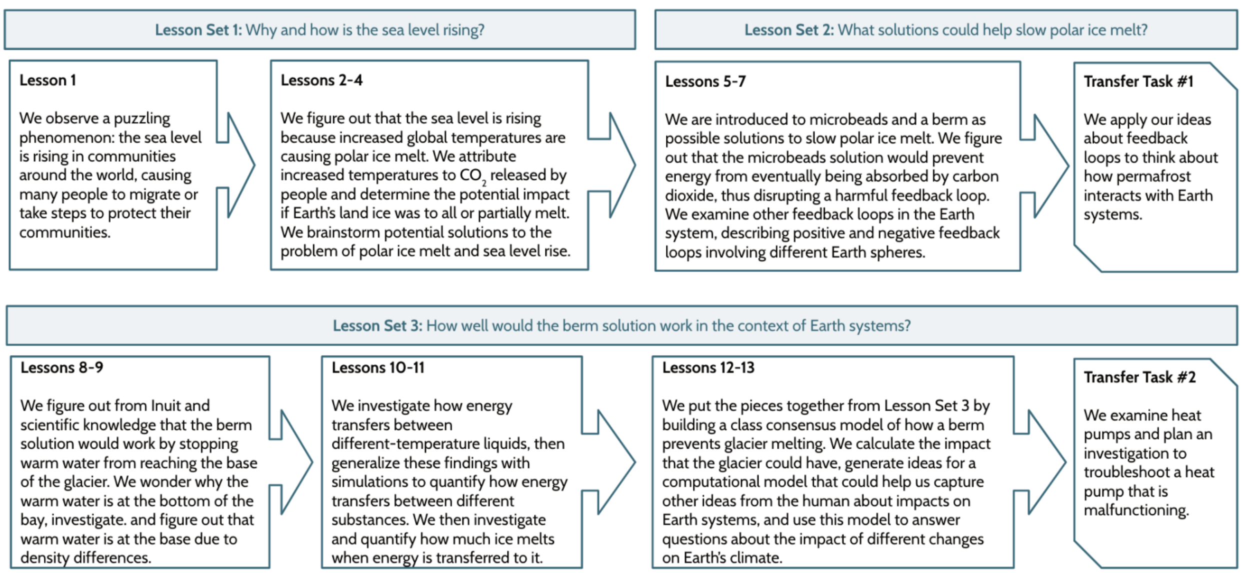
As students engage with a unit of instruction in OpenSciEd High School, they seek and use evidence to figure ideas out as they build, evaluate, and revise explanations, models and arguments. Evidence comes from investigations, simulations, new data, reliable scientific texts, and interviews with trusted friends, family and community members. Students use evidence from multiple sources to move their thinking forward in the context of the storyline, rather than relying on the authority of the teacher or the text.

For more information about how OpenSciEd HS is designed to be collaborative and equitable, see the Attending to Equity and Supporting Classroom Discourse sections.

Organization of OpenSciEd Units

OpenSciEd High School units are organized into collections of lessons called *lesson sets.* Each lesson set advances the storyline by investigating one aspect of the anchoring phenomenon. In each lesson set, 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 began the lesson set with.

The individual lessons that make up a lesson set incorporate routines to help students make sense of the anchoring phenomenon through several steps or activities that work together (see the next section, OpenSciEd Routines for more detail). Lessons range in length from one class period to several. Here is an example of the how the lessons and lesson sets are organized in OpenSciEd Chemistry Unit 1: *Polar Ice*:



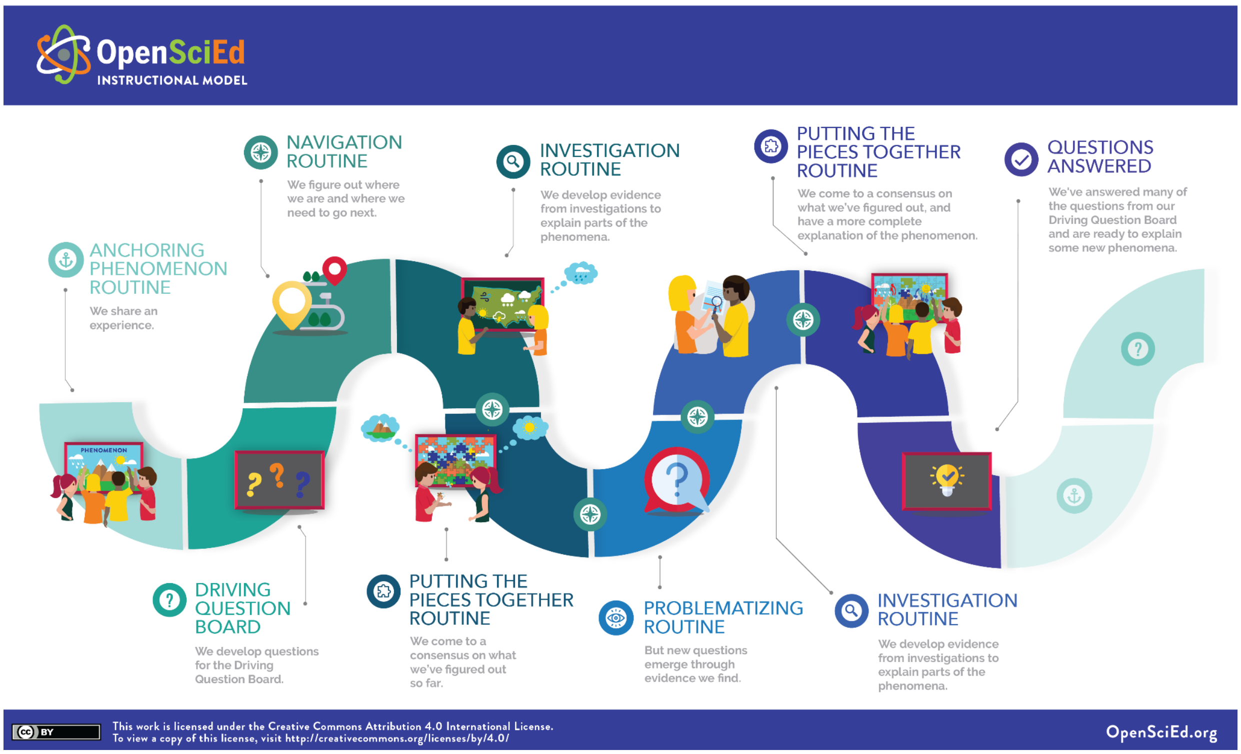
Teacher- and Student-Facing Materials

Each OpenSciEd unit has several components. There is a teacher edition for each unit that includes teacher guides for each lesson which describe 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 not intended to be used as a script but rather as suggestions for how to implement the lessons, which teachers can use in planning instruction for their specific settings and students. The teacher edition also provides teachers with additional lesson resources, such as teacher reference documents that provide guidance such as investigation setup instructions, keys, as appropriate for the lesson, and each lesson has a set of presentation slides with notes that teachers can project and use as they move through each lesson.

Each unit also includes a student edition, which provides readings, references, and lesson procedures for each lesson. Students can use the student edition during lessons, or to re-create any missed investigations in the case of an absence. In addition to this student edition, there are student handouts designed for situations where students need to draw or write as they progress through a lesson. These handouts are designed to be printed, copied and three hole punched for each student and are intended for students to keep in their science notebooks. All students need to have a science notebook, a three ring binder with loose-leaf paper, to use for written work and to keep track of handouts and other documents throughout the unit. Students can access interactive resources, such as simulations, videos, or other media as they are figuring out science ideas through the student materials.

OpenSciEd Routines

OpenSciEd organizes student sensemaking around routines—activities that play specific roles in advancing the storyline with structures to help students achieve the objectives of those activities. OpenSciEd units use five routines drawn from the work of the NextGen Science Storylines Project (Reiser, Novak, McGill, 2017): the Anchoring Phenomenon, Navigation, Investigation, Putting the Pieces Together, and Problematizing Routines. The following sections discuss what occurs during each routine in detail.



Anchoring Phenomenon Routine

Kicking off a Unit with an Experience to Motivate Investigation

The Anchoring Phenomenon Routine is used to kick off a unit of study and drive student motivation throughout the unit. The Anchoring Phenomenon Routine should build a shared mission for students to figure out phenomena or solve design problems. More specifically, the Anchoring Phenomenon Routine serves to ground student learning in a common experience and then use 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 as it:

- 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;
- exploses 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.

Elements of the Anchoring Phenomenon Routine

Element 1: Explore the Anchoring Phenomenon

Every OpenSciEd unit starts with a puzzling phenomenon or problem that students experience and explore. In this initial exploration the class often focuses on their initial noticings and wonderings. 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.

In the following example from OpenSciEd Physics Unit 1 *Electricity*, students are (A) introduced to the blackout that occurred in Texas in 2021. (B) They share their thinking about this event and (C) investigative data to notice and wonder about the patterns they see in the blackout map.

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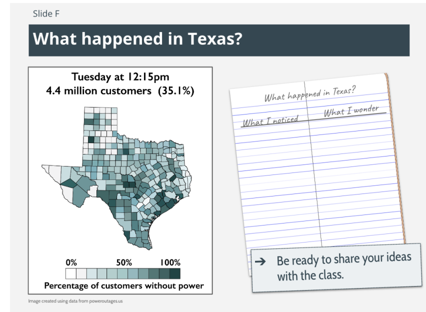

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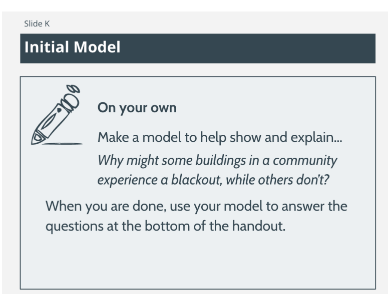
Element 2: Attempt to Make Sense

As students attempt to make sense of the phenomenon they develop an initial explanation or model. The role of the teacher in this part of the routine is to (1) help students share their thinking, welcoming all ideas and (2) push students to come up with a tentative mechanistic explanation. At this stage students will be unable to develop a full mechanistic explanation. Their explanation will serve as the motivation for the investigations they will carry about that will lead them to build a more sophisticated scientific understanding. By trying to make sense of the phenomenon themselves, students will generate ideas that lead to questions and theories they will want to investigate.

In the following example from OpenSciEd Physics Unit 1 *Electricity*, students (A) develop an initial model on their own, (B) conduct a gallery walk to consider how their ideas compare to others and (C) develop a class consensus model.



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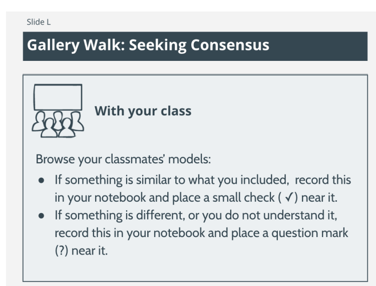

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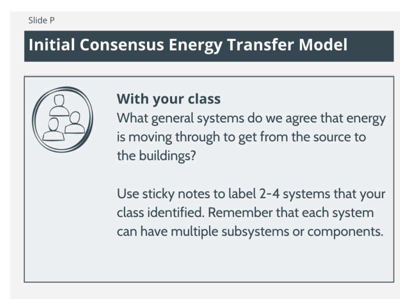

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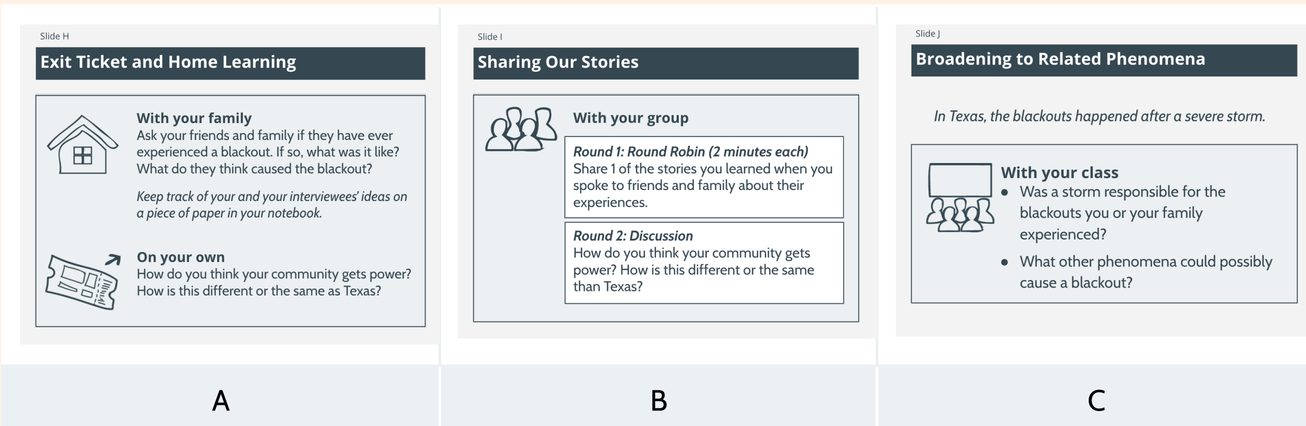
Element 3: Identify Related Phenomena

The goal of OpenSciEd units is not just to explain one phenomenon. The goal is to build three dimensional understanding 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 an opportunity to make personal connections to the events being explored in class.

In the following example from OpenSciEd Physics Unit 1 *Electricity*, students (A) use a home learning opportunity to connect with their communities, (B) share their stories with their classmates and (C) consider how storms and other phenomena cause blackouts.

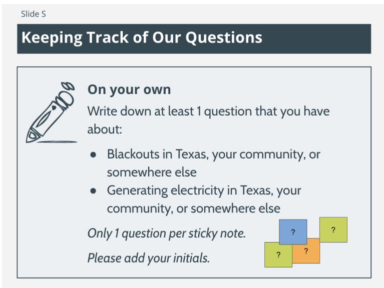


Element 4: Pose Questions for the Driving Question Board and Discuss Next Steps
In the fourth element, the class uses a Driving Question Board (DQB) to generate, keep track of, and revisit student questions related to the anchoring phenomenon and related phenomena. Its use in OpenSciEd draws from work on project-based science learning, e.g., Singer, Marx, Krajcik, & Chambers (2000), Weizman, Schwarz, & Fortus (2010), and Nordine & Torres (2013). The Driving Question Board is a central support for the OpenSciEd 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.

Driving Question Board

Through the DQB, students have an opportunity to be a decision-maker about what the class should figure out and how the class will go about their investigations. It is important for each student to participate in generating at least one 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 about ways to answer one or more of the questions from the DQB.

In the following example from OpenSciEd Physics Unit 1 Electricity, students (A) develop individual questions whose answer would help them explain the phenomenon, (B) make their questions public by adding them to the DQB and (C) brainstorming how to investigate the questions they posed.



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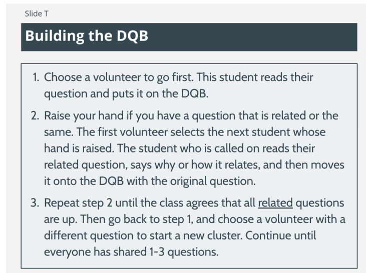

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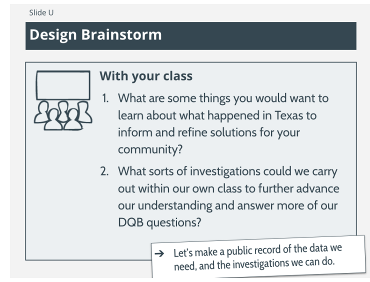

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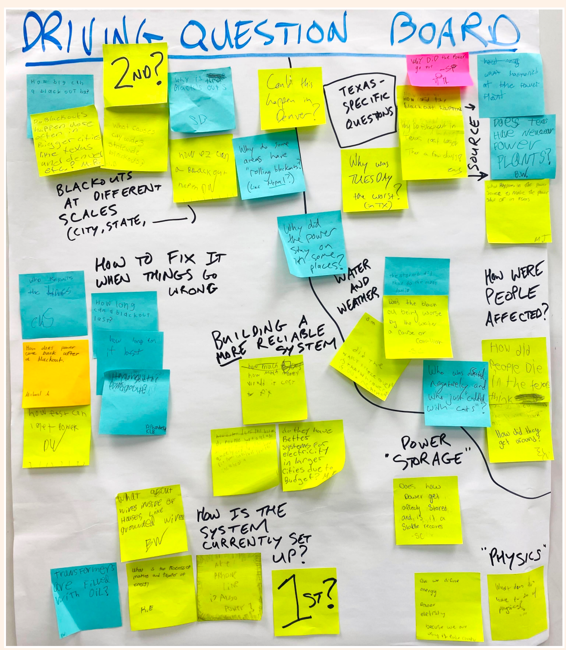


The DQB is a visual representation of the class's shared mission of learning in the unit. The DQB is publicly displayed to serve as a learning resource for the community and should be easily accessible to students to see and add to during the unit. DQBs can be constructed with sticky notes or sentence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

When is the DQB used?

A DQB is introduced at the beginning of each unit in the Anchoring Phenomenon routine, and then revisited by the class as part of the Navigation, Putting the 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 not meant 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.

For more resources about creating the DQB, see the Appendix.

OpenSciEd Navigation Routines

Anchoring Phenomenon	Navigation	Investigation	Putting the Pieces Together	Problemitizing

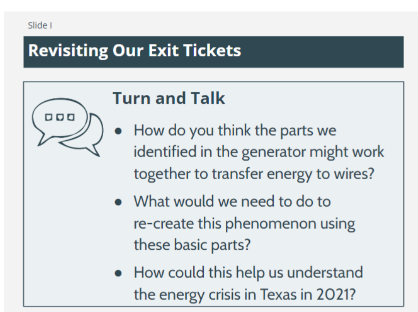
Navigation Routine

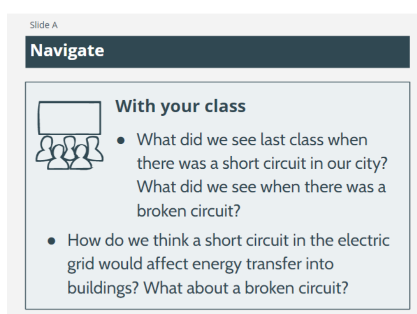
The Navigation Routine supports student coherence in a storyline by helping teachers and students identify the connections between activities and lessons. Each activity and lesson has a purpose and is connected to what has gone before and what is coming next. It also provides a valuable opportunity for students to reflect on their learning over time. The Navigation Routine is different from the other routines in that it is not the focus of a specific lesson, rather it is a feature included within lessons. The Navigation Routine happens throughout the unit, typically at transition points between activities and lessons. *Note: Not all of the elements described below are incorporated into every Navigation Routine found in a lesson.*

Typical Elements of the Navigation Routine

Element 1: Look Back: How did we get here?
Sometimes at the beginning of lessons or between instructional days of a single lesson, the class is asked to reflect on the progress of their learning by revisiting where their progress towards figuring out the anchoring phenomenon or solving the unit design problem. Teachers may prompt students to do the following when this Navigation Routine element is implemented:

- Provide students with individual think time, a moment to stop and jot, time to turn and talk with a partner, or discuss with the class what they figured out previously.
- Review data from previous class' exit tickets.
- Use the Progress Tracker individually, in partners, or small groups to track progress toward answering a question.





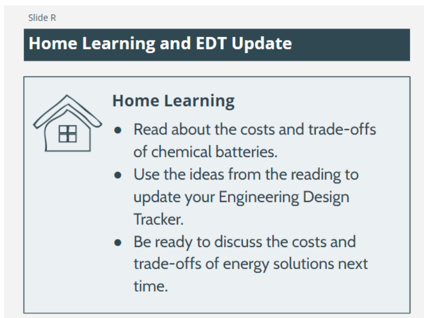
Element 2: Take Stock: Where are we now?
There are many time points during a lesson that the class might be able to assess progress in the lesson to strengthen connections between activities and the storyline. These time points include the following:

- During and after investigations, 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

- In multi-day lessons, students are often prompted to take stock in what they have done so far in the lesson and reflect on what is left to accomplish. Students may also be prompted on the following instructional day to reflect on what they figured out the prior day.
- Home Learning can be used to help students continue to make sense of their learning or gather information from others as they make connections between home and school.

Teachers may prompt students to do the following when the Navigation Routine element is implemented:

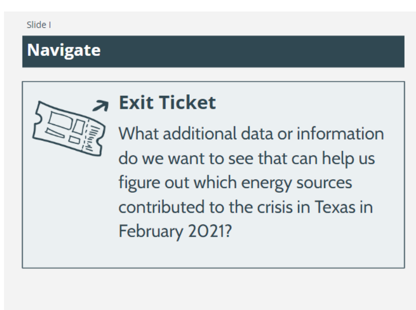
- Returning to the Driving Question Board to answer questions.
- Add to their Progress Tracker.
- Revise their initial models to incorporate new information.
- Discuss what we have figured out so far and what is left to investigate.
- Complete and discuss their findings from a Home Learning assignment.

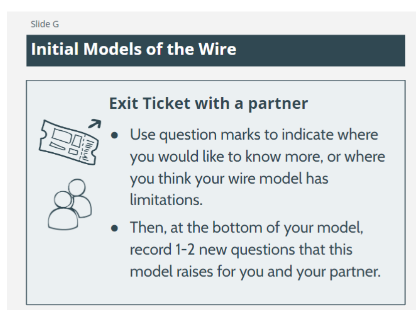


Element 3: Look Forward: Where are we going?

Often, to set up the upcoming lesson or day, students are asked to think about what next steps will help them make progress on their ideas and move their thinking forward. This is an opportunity to give students a sense of ownership in the direction of the next lesson. Teachers may prompt students to do the following when this Navigation Routine element is implemented by:

- Returning to the Driving Question Board to add new questions or determine which set of questions to answer next.
- Brainstorming ideas or complete an exit ticket about where the class should go next, what investigations they should do, or what information they need to continue to make progress on their ideas.





Investigation Routine

The purpose of this routine is to answer the questions generated during the anchoring phenomenon routine. Students incorporate the ideas they figure out through their investigations into their developing mechanistic explanations and models. Most lessons in OpenSciEd use the Investigation Routine.

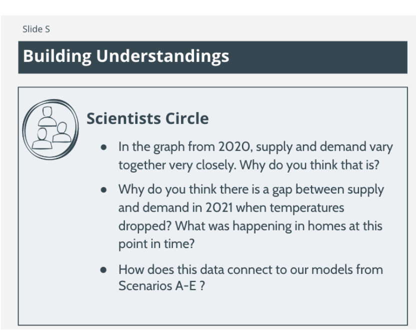
Typical Elements of the Investigation Routine

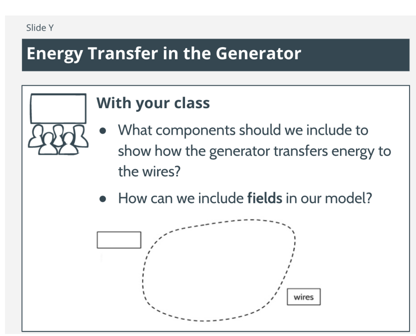
Element 1: Create a Plan of Action
In the first element, the class works together to articulate a plan of action for investigating a particular question or to discuss why certain things might be measured or attended to during an investigation. This element helps the class figure out their question.

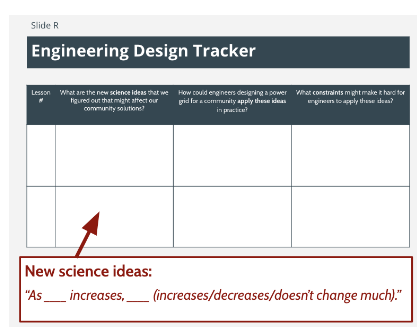
Element 2: Do the Work with Science and Engineering Practices
Students use science and engineering practices to investigate their questions. For example, in OpenSciEd Physics Unit 1 Electricity, students:

- Develop, revise, and use a model to identify structures that affect energy transfers across and between systems at different scales.
- Analyze multiple types of data about energy sources that increase the reliability of the energy grid
- Use a simulation to model electron flow inside to determine relationships between independent and dependent variables involving electrical energy transfer that can be interpreted to reengineer and improve the electric grid.

Element 3: Make Sense: What did we figure out?
As students figure out the answers to their questions they pause to make sense of both the science ideas and how they relate to the anchoring phenomenon. Students might (A) engage in a discussion, (B) revise the class consensus model, or (C) update their Progress or Engineering Design Trackers.







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OpenSciEd Navigation Routines				
Anchoring Phenomenon	Navigation	Investigation	Putting the Pieces Together	Problemitizing

Putting the Pieces Together Routine

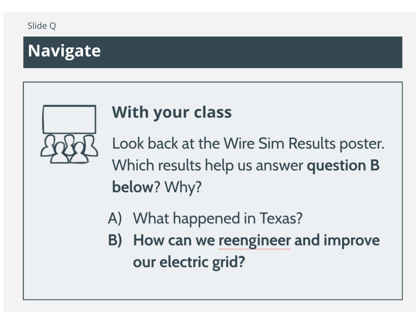
In the Putting the Pieces Together Routine, students synthesize ideas they develop across multiple lessons and figure out how to put them together to explain the anchoring phenomenon. Elements of this routine may occur throughout several lessons, including at the end of a lesson set, and/or at the end of the unit.

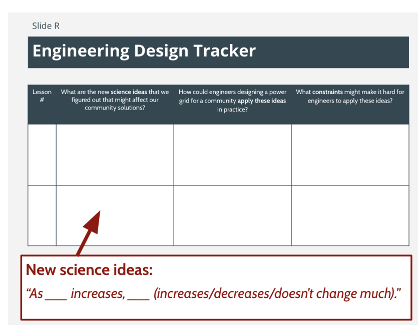
Typical Elements of the Putting the Pieces Together Routine

Element 1: Take Stock

Students need time to reflect on what they are trying to figure out; to take stock of the main science ideas the class has figured out so far. Then, students need to determine which evidence generated through their investigations might be helpful for them. Students may highlight important discoveries they made in their science notebooks, revisit their Progress Trackers or Engineering Design Trackers (see the Assessment System section for more information), or develop a Gotta-Have-It Checklist to organize their ideas.

In the following example from OpenSciEd Physics Unit 1 *Electricity*, students in Lesson 6 (A) connect ideas from a simulation to their larger engineering task, and (B) then add these ideas to their Engineering Design trackers.





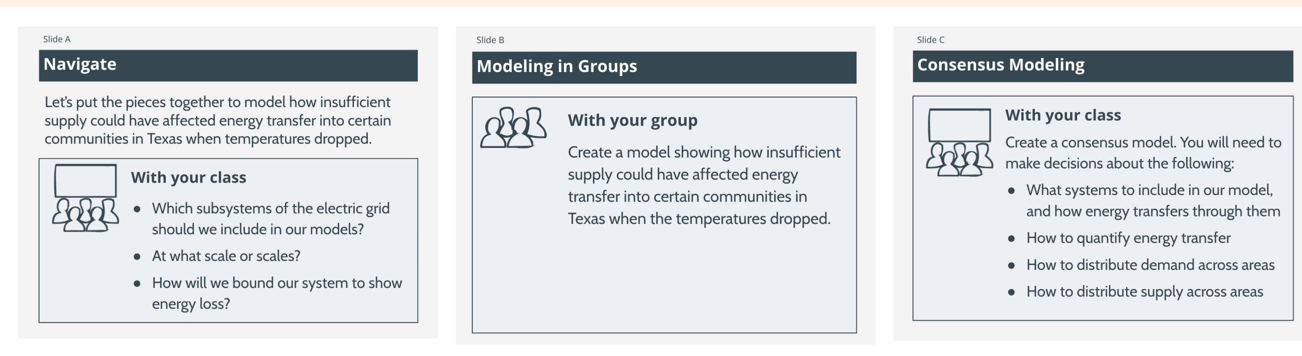
A	B

Element 2: Put Pieces Together

The second element of the routine involves several steps that allow for independent, small group, and whole class thinking including:

- Students work individually to synthesize the evidence and formulate their ideas. Students may follow a Gotta-Have-It Checklist to guide this thinking or they may use information the class determined was important to their learning.
- Students share and revise their ideas with a partner or in small groups. This can create a safer space for students who might be less willing to participate in a larger setting. In addition, this helps partners or small groups identify ideas or features they want to bring to the class consensus model.
- The class participates in a Consensus Discussion where students draw on their work to share and evaluate alternate models or explanations. During this process, as the class puts their ideas together, they develop a public representation, such as a revised class consensus model.

In the following example from OpenSciEd Physics Unit 1 *Electricity*, students spend time in Lesson 7 to put the pieces together (A). To do this, they (B) work in small groups to create a model on loose-leaf paper that they can put in their notebooks. They are given guidance to model at the macro scale, and to include more than one power plant, a transport system, and at least two communities. After the small groups have created their models, (C) the class moves to create a consensus model.



A	B	C

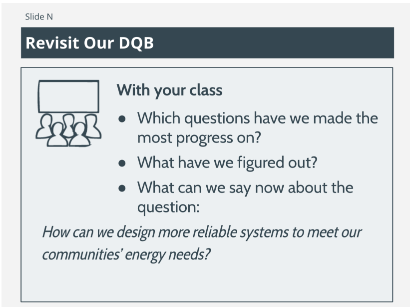
Element 3: Revisit the Driving Question Board

Depending on when this routine happens in the unit, students may consider what pieces they have just put together or take stock of what they have figured out, and then revisit the questions on the Driving Question Board. They may identify and add additional questions that need to be investigated as the class moves into the next lesson set.

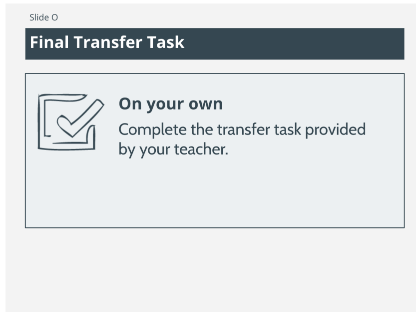
Element 4: Apply This to Another Phenomenon

After the class comes to a consensus on a model 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.

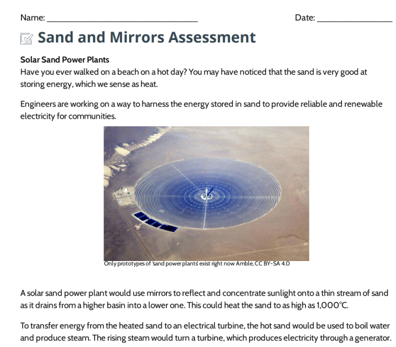
In the following example from OpenSciEd Physics Unit 1 *Electricity*, after students create a class consensus model, they analyze more data, revisit their models, conduct a scientist circle, and interview interested parties. In Lesson 11, they revisit the DQB (A). Then they apply their learning to a transfer task (B) about solar sand power plants (C).



A



B



Name: ______________________ Date: ____________

Sand and Mirrors Assessment

Solar Sand Power Plants
Have you ever walked on a beach on a hot day? You may have noticed that the sand is very good at storing energy, which we sense as heat.

Engineers are working on a way to harness the energy stored in sand to provide reliable and renewable electricity for communities.

Only prototypes of 'sand power plants' exist right now Amble, CC BY-SA 4.0

A solar sand power plant would use mirrors to reflect and concentrate sunlight onto a thin stream of sand as it drains from a higher basin into a lower one. This could heat the sand to as high as 1,000°C.

To transfer energy from the heated sand to an electrical turbine, the hot sand would be used to boil water and produce steam. The rising steam would turn a turbine, which produces electricity through a generator.

C

OpenSciEd™ Navigation Routines

Anchoring Phenomenon	Navigation	Investigation	Putting the Pieces Together	Problemitizing

Problematizing Routine

The purpose of the Problematizing Routine is to reveal potential gaps in the class's understanding of the current model, explanation, or design solution in order to motivate students to develop additional questions or investigations. The Problematizing Routine is often used in a lesson following a lesson using the Putting the Pieces Together Routine or at the beginning of a lesson set where it is critical for students to recognize the limits of their current explanations.

Typical Elements of the Problematizing Routine

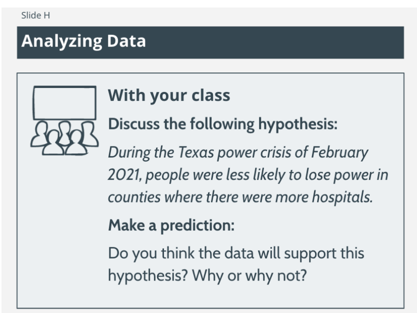
Element 1: Identify Aspects of the Anchoring Phenomenon That the Consensus Model Cannot Explain
The class works to identify gaps in their understanding of the anchoring phenomena or design problem by identifying areas of disagreement or confusion when developing explanations. The role of the teacher is to press students to determine whether the key science idea(s) they have developed so far can fully explain the phenomena or solve the problem.

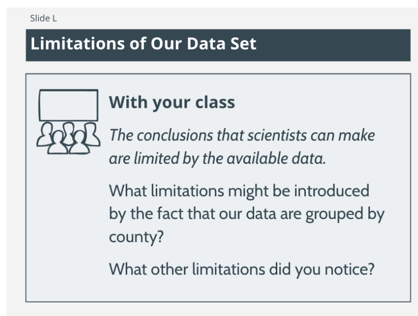
Element 2: Understand the Limits of the Model and Consider Ways to Revise It
The class may work to generalize the consensus model and apply it to another phenomenon. The teacher may have students evaluate how well the generalized model works to explain the new phenomena. Students can identify gaps in the ability of the generalized model to explain the new phenomena.

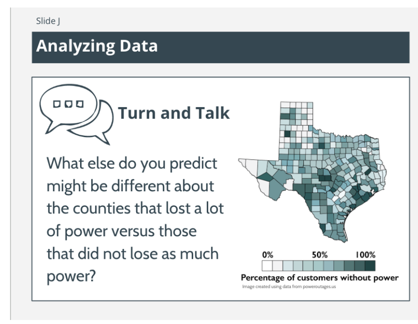
Element 3: Pose Questions to Resolve and Discuss Next Steps

Both *Elements 1* and *2* provide students opportunities to develop additional investigative questions. The teacher should prompt students to record these new questions and add them to the DQB. This important revision to the DQB works to continue to drive the learning for the next portion of the unit. Additionally, students could also identify possible investigations they could conduct to answer their new questions. These ideas could be added to the *Ideas for Investigations*.

For example, in OpenSciEd Physics Unit 1 *Electricity*, students figure out what happened in Texas during the 2021 blackout and their models in Lesson Set 1. In Lesson 7, they realize that their model cannot explain why some counties lost power and others did not. This prompts students to ask why some people were affected differently by decisions to shut off power in certain communities which they investigate in Lesson 8.







The Role of Teachers and Students During the Routines

Teachers and students work together to make progress on explaining the anchoring phenomenon. As they do they assume various roles. The table below describes the roles of the teacher and students when enacting the teaching routines.

Routine	Role of Teacher	Role of Student
Anchoring Phenomenon	Anchor students' science work in questions their class has developed, recorded on the Driving Question Board.	Explore, attempt to make sense of, ask questions around, and identify initial investigations to explain the anchoring phenomena.
Navigation	Position students as partners in figuring out how to make progress on their questions.	Reflect on the progress made towards answering class questions and determine where to go next.
Putting the Pieces Together	Partner with students in the process to develop explanations, models, and solutions.	Work individually and collaboratively to develop explanations, models, and solutions.
Problematizing	Work collaboratively with students to identify unanswered questions and explanatory gaps to direct further work.	Identify areas of disagreement in models when applied to a new situation.

Integrating the Three Dimensions

In OpenSciEd High School, each unit of instruction builds toward a set of NGSS performance expectations. The performance expectations were designed as end of year or grade band assessment targets. As such, students should not be expected to demonstrate mastery of the NGSS performance expectations at the end of individual lessons. Each lesson's learning goals are articulated by one or more Lesson Level Performance Expectations (LLPEs) and can be found in the *Teacher Guide* for each lesson.

How Students Use the Three Dimensions

NGSS Dimension	Description
Science and Engineering Practices (SEPs)	**Students use SEPs to make sense of science ideas.** For example, in OpenSciEd Biology Unit 1: *Serengeti,* students analyze and interpret data and develop and used models to figuring out how limiting factors affect populations of migrating mammals. The SEPs are intended to be used by students in the classroom as they are used by practicing scientists in their everyday work.
Disciplinary Core Ideas (DCIs)	**Students make sense of how and why phenomena occur using DCIs.** For example, in OpenSciEd Physics Unit 2: *Afar,* students use DCIs about how waves are affected by the medium through which they pass to understand why seismic waves slow down as they pass through the middle of the Earth. The *OpenSciEd HS Scope and Sequence* provides a pathway through which students can coherently build understanding of the target Life Science, Physical Science, Earth and Space Science and Engineering, Technology and the Applications of Science DCIs across the three courses. Students may also draw on DCIs developed in the prior grade bands (K-8) and in prior units.
Crosscutting Concepts (CCCs)	**Students apply CCCs to make sense of a phenomenon using the SEPs**. For example, in OpenSciEd Chemistry Unit 1: *Polar Ice*, students explain why sea ice is melting at accelerating rates. As they do, they apply crosscutting concepts about energy transfer to make sense of the results of an investigation where the atmosphere and the hydrosphere in a closed system interact. The CCCs provide a lens through which students ask productive and investigable questions. They provide a set of principles and heuristics to guide model building and explanation, and a way to frame students' experiences of related phenomena.

The three dimensions are integrated into the storyline of each unit. Each unit **intentionally develops** the use of a subset of SEPs and CCCs to support students as they figure out DCIs. Student use of practice and crosscutting concepts are intentionally developed and purposefully scaffolded as students engage with the elements, are introduced to new elements that have not been used before, and/or engage in applying elements to a new context. While not all SEPs and CCCs are intentionally developed within a single unit, additional elements of the SEPs and CCCs are **key to student sensemaking**. The example below from the *Teacher Background Knowledge* section of OpenSciEd Biology Unit 1: *Serengeti* Unit Overview provides a narrative of this integration.

This unit is designed to introduce students to ecosystems, their dynamic nature, and the interactions within them. Developing and using models **is intentionally developed across this unit**, beginning in Lesson 1, where students develop initial models to explain ecosystems they explore in their conservation profiles. In Lessons 3 and 4, students develop and revise a model of the great migration in the Serengeti. In Lesson 5, they use multiple models to explain carrying capacity in the wildebeest population. In Lesson 8, they use these models to generate data to explain predictions about disturbances to the system. Student models use stability and change to explain interactions in the system, and this crosscutting concept is intentionally developed throughout the unit.

The use of mathematics and computational thinking **is intentionally developed in this unit**. In **Lessons 4 and 5,** students use mathematical representations of phenomena. In **Lesson 5**, students use rates of change to understand how limiting factors affect a population. In **Lessons 5 and 7,** students develop algorithms to explain relationships. In **Lesson 8,** students use a mathematical model to explain and predict interactions in the Serengeti system.

Constructing explanations and designing solutions **is also intentionally developed in this unit**. In **Lesson 9,** students evaluate a real-world problem related to a proposal to build a road through the Serengeti. In **Lesson 10,** student explanations focus on the conservation profiles introduced in Lesson 1. Students use everything they have figured out throughout the unit to evaluate conservation in these systems.

While not intentionally developed, obtaining, evaluating, and communicating information is also **key to the sensemaking** in this unit. Patterns, and systems and system models are also key to the sensemaking in several lessons.

How the Three Dimensions Are Communicated in Units and Lessons

In OpenSciEd High School each lesson's learning targets are expressed as three dimensional lesson level performance expectations (LLPEs). In the example below, note the color coding of the LLPE, blue=SEP, orange=DCI and green=CCC. The codes following the LLPE (SEP: 2.3; DCI: PS3.B.2, PS3.D.1; CCC: 4.3) align to the elements listed in the foundation box below and the *Elements of NGSS Dimensions* supplemental material.

3.A Develop and use a model based on evidence to illustrate the energy flow between components of the electric grid system and energy loss from the system as a possible cause of the crisis in Texas. (SEP: 2.3; DCI: PS3.B.2, PS3.D.1; CCC: 4.3)

3D Elements Addressed in This Assessment
2.3 Developing and Using Models Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
PS3.B.2: Conservation of Energy and Energy Transfer Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4)
PS3.D.1: Energy in Chemical Processes and Everyday Life Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3),(HS-PS3-4)
4.3 Systems and System Models Models (e.g., physical, mathematical, computer mo/dels) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Assessment System

The OpenSciEd High School assessment system reflects principles outlined in the National Academies of Science Engineering and Medicine (2017) report, Seeing Students Learn Science: Integrating Assessment and Instruction in the Classroom, as well the joint guidelines developed by EdReports and NextGenScience (2021) for critical features of assessment presented in Critical Features of Instructional Materials Design for Today's Science Standards. Like all of the instructional materials in OpenSciEd, assessments adopt an asset based perspective on student thinking; one in which students' partial understandings, noncanonical ideas, everyday experiences and ways of describing phenomena are potentially important resources for their learning (Warren et al., 2001). In fact, each learner may bring different kinds of ideas and intuitions to learning, and they may also view elements held in common with others in different ways (diSessa et al., 2016). Treating students' ideas as resources is important in both instruction and assessment, as it helps create a safe space for students to share their "first draft" thinking. Students' sense of belonging and their sense of whether they need to have the correct idea both influence whether they contribute to knowledge building (Clarke et al., 2016).

Purposes of the Assessment System for OpenSciEd

The assessment system in OpenSciEd is designed to support classroom teaching and learning. OpenSciEd instructional materials provide frequent formative and summative assessment opportunities to monitor student progress toward the NGSS performance expectations targeted in each unit. The OpenSciEd instructional model is focused on students figuring out phenomena, building ideas over time, revising their thinking, and working collaboratively. Assessments are designed to be aligned with that model. The assessment system in OpenSciEd includes assessments with different purposes that each support sensemaking in different ways.

The assessment system integrates:

- Tasks with multiple components that require students' integrated use of all three dimensions of the NGSS (disciplinary core ideas, science and engineering practices, and crosscutting concepts) in the context of explaining phenomena and solving problems;
- Support for teachers to document students' learning progress toward more sophisticated understandings;
- Support for students' reflection on their own learning through self- and peer-assessment;
- Materials that provide students and teachers with feedback they can use to improve learning; and
- Tools for teachers to understand their students' experiences of the materials.

Types of Assessment Embedded in Materials

The assessment opportunities in OpenSciEd High School are designated as formative or summative as described in the table below. In general, **formative assessment** opportunities provide teachers with information about student progress related to lesson level performance expectations (LLPEs). They are embedded and called out directly in the lesson and are indicated with a check mark icon in both the learning plan snapshot and within the text of the teacher guide.

Assessment opportunities are accompanied by callout boxes that include "look and listen for's" and guidance for teachers about instructional decisions. While most formative assessments in

OpenSciEd are designed for the teacher to provide feedback, there are opportunities for students to provide feedback through self-assessment and peer assessments. **Summative assessments** typically occur at the end of a lesson set or unit and are designed to provide teachers with information about how students have synthesized and can apply their learning to novel contexts.

OpenSciEd Opportunities for Assessment			
Type		Purpose	Examples
Formative	Pre Assessment	• WHAT: Uncovers the diverse sets of ideas that students bring with them to instruction. • WHEN: Typically found early in Lesson Sets. • WHY: Makes visible a diverse set of student ideas that can be leveraged to build on students' current understandings, connect to student interests & experiences, promote equity and support sensemaking.	• Initial Models • Questions on DQB
	Embedded Assessment	• WHAT: Conducted during the course of instruction to monitor student learning and inform instructional decisions. • WHEN: Built into every lesson of the unit and supported with assessment callout boxes in the teacher guide. • WHY: Provides information about students' progress towards the LLPEs to support teachers in providing feedback and making instructional decisions.	• Individual or small group model • Exit ticket • Whole group discussion • Progress Tracker
	Self-Assessment	• WHAT: Students reflect on their learning, community engagement, and growth. • WHEN: Embedded in key places, usually after important discussions or investigations, and can be added anywhere throughout the unit. • WHY: Provides information to students about their thinking, learning process and growth.	• Discussion Assessment • Self Assessment & Peer Feedback on Explanations • Teamwork Self Assessment
	Peer Assessment	• WHAT: Students give/receive actionable feedback to support revision • WHEN: As part of tasks/investigations that elicit complex and diverse ideas where not all student work is the same. • WHY: Supports culture of collaboratively figuring out, provides students more opportunity for feedback and leads to ownership of learning.	• Peer Feedback Guide • Investigation Plan Peer Feedback • Sticky note peer review • Peer review with unit rubrics
Summative Assessment		• WHAT: Evaluate what students have learned at a key point in the unit as a result of instruction. They are three-dimensional and aligned to a PE or to a LLPE. • WHEN: Often at the end of a Lesson Set and unit. • WHY: Provide teachers with information to determine what students have figured out relative to key elements of the unit performance expectations.	• Transfer Task • Individual model • Written explanation • Midpoint assessment

While the majority of assessment moments are embedded in the lessons, and vary in format, there are a few key tools that provide a more systematic way to keep track of student ideas over time. These include Progress Trackers, the Electronic Exit Tickets, and the summative assessment opportunities (such as Transfer Tasks), described below.

Progress Trackers

Students regularly update a Progress Tracker where they summarize what they figure out and/or revise their developing models and explanations. Progress Trackers are intended to be used formatively rather than summatively because they help students document their evolving models, understandings and questions about where to go next. Students' individual Progress Trackers provide an opportunity to directly document their growing understanding of the phenomena and problems they are investigating. These are updated regularly within units.

Electronic Exit Tickets

Units also include Electronic Exit Tickets intended to provide insight into how students' developing ideas align with learning goals at critical points in the unit. Exit tickets include several multiple choice questions that each integrate two dimensions (e.g. DCI-SEP, DCI-CCC, SEP-CCC). Additional open response questions ask students to reflect on Community Agreements, relate the day's lesson to something in their everyday lives, or to reflect on the utility of a crosscutting concept or practice in making progress on science ideas. Electronic Exit Tickets often include questions designed to elicit students' experience of the day's lesson and provide information about whether the lesson was coherent from the student's perspective (Reiser et al., 2021). A lesson is coherent when students see their science work as making progress on questions and problems their classroom community has committed to address, rather than simply following directions from textbooks or teachers. The exit tickets also provide information about whether students perceived lessons to be relevant to their lives and important to their communities. A key goal of the Framework for K-12 Science Education (National Research Council, 2012) is that students should have opportunities to pursue questions related to their own interests and community concerns. Exit tickets also provide information about whether students contributed to knowledge building and felt that their ideas were heard. Communicating science ideas is a key part of the instructional model and critical to productive engagement with science practices (Agarwall & Sengupta-Irving, 2019).

Transfer Tasks

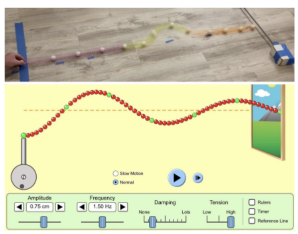
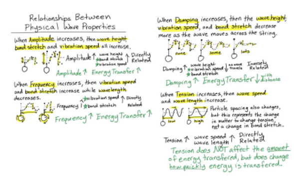
Each unit includes one or more Transfer Task(s) that require students to apply what they have figured out in the unit to a new phenomenon or problem. Transfer Tasks are typically found at the end of a unit; some also include mid-point transfer tasks and may be found at the end of a lesson set. Each transfer task is designed to provide information about student proficiency with respect to targeted DCI, SEP, or CCC elements. Students can complete these tasks individually and they can be used as evidence of student learning.

Assessing and Providing Feedback on Student Progress

A key way students learn is by using multiple modalities to make their thinking visible. Sharing one's thinking is always an act of vulnerability, thus assessing student learning is a moment of both risk and opportunity for learning. When assessing individual students it is critical to consider how the assessment impacts the relationship between teachers and students and among students. While it is critical for students to be able to understand their progress toward mastery, students can easily attach labels intended to describe qualities of student work to themselves. Likewise, when giving feedback to students, the best feedback is specific, grounded in evidence students have presented, task-focused, and oriented toward next steps students can take (Black & Harrison, 2001; Kluger & DiNisi, 1996).

In OpenSciEd High School units, students build understanding together and incrementally as the class answers questions students identify and agree to pursue in the service of explaining phenomena and solving problems. As such, one of the key resources within units for examining how student learning is expected to progress is the *What we do and figure out* column of the unit storyline.

In the following example from the OpenSciEd Physics Unit 5 *Microwaves*, the unit storyline identifies what students will figure out about energy, waves, amplitude, frequency, and wavelength in Lesson 3:

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 3 Lesson Set 1 3 days **How does energy transfer through a wave?** Investigation	 *Shaking the end of a slinky creates a wave pattern. A computer simulation of a wave on a string produces similar patterns.*	We recall examples of physical waves and produce waves with a spring. We develop a model of how physical waves transfer energy through solids. We use a computer simulation to plan and carry out four investigations. Using our results, we make claims for how various wave properties affect energy transfer. We develop a mathematical model of the relationship between some of these properties. We figure out: • Energy is transferred through waves on a string by the stretching of electric fields (bonds) and by the forces between these fields and the matter of the string. • A larger amplitude transfers more energy along the wave. • A larger frequency transfers more energy along the wave. • The wavelength of a wave can be determined by the wave speed across the medium and its frequency.	

⇩ **Navigation to Next Lesson:** We think that the multiple perspectives (M-E-F) we have used to explain energy transfer in physical waves could also help us make sense of how energy transfers from the magnetron to the food inside the microwave oven.

Together, the different forms of assessment discussed above provide a body of evidence that teachers can use to assess whether the class as a whole is ready to move forward to the next lesson or lesson set. When a significant proportion of students need additional support, guidance is provided as "Suggestions for Instruction". This approach to learning prioritizes the work of the class as a whole in building understanding and allows students to experience the collaborative nature of scientific work. Thinking of the goal as moving the whole class forward requires all students to have sufficient understanding to contribute in an ongoing way to knowledge building, motivating equitable participation and understanding in the classroom.

Feedback and Instructional Decisions: Formative Assessment Opportunities

Assessments embedded within individual lessons are intended to provide evidence to teachers about student progress on lesson level performance expectations (LLPEs), the three-dimensional learning goals for individual lessons. Individual lessons may have one or more LLPE(s) and there are multiple kinds of opportunities for assessing LLPEs at the lesson level, as described below:

ASSESSMENT OPPORTUNITY	**What to look for/listen for in the moment:** • Modeling energy transfer across more than one system (e.g., the power plant, substation, and buildings) and using question marks to indicate areas of uncertainty. (SEP: 2.3) • Using numbers or symbols to quantify energy coming in and out of various parts of the system (e.g., the buildings, power plant, and/or substation). (CCC: 4.3) • Indicating that the energy coming into the substation from the power plant is equal to the total energy leaving the substation to buildings and the surroundings. (DCI: PS3.B.2) • Models for Scenarios A and B include an arrow to indicate a connection between parts of the electric grid and the surroundings, to account for the energy loss in the system. (CCC: 4.3) **What to do:** Walk through the classroom as students complete their energy transfer models. Use the following prompts to encourage students to identify areas of uncertainty and to support their ideas with evidence we have seen. • *What do you think you will see when...?* • *Do we have any evidence to support that idea?* • *What assumptions are you making about the energy used by...?* Call on students' previous knowledge about how energy cannot be created or destroyed as they try to add numbers to their models. Say, *I see that __ energy goes into the substation, but only __ comes out. Where did that extra __ energy go?* Encourage students to explore the limitations of their models. Say, *Are you certain of the exact amount of energy that transfers in your models? What are you certain of? Where can you use a question mark to show you're less certain?* **Building toward: 3.A** Develop and use a model based on evidence from our investigation in Lesson 2 to illustrate the energy flow between components of the electric grid system and energy loss from the system as a possible cause of the crisis in Texas. (SEP: 2.3; CCC: 4.3; DCI: PS3.B.2, PS3.D.1)

Feedback and Instructional Decisions: Summative Assessment Opportunities

Each unit includes one or more Putting the Pieces Together lesson(s) where students put together the science ideas they have figured out so far in a consensus model. These assessments are designed as entire lessons, and are opportunities for tracking group progress toward the key learning goals for the units. There are both individual and group components in Putting the Pieces Together lessons. Individual components are intended to provide teachers with evidence that could be used either formatively or summatively to assess student understanding developed in the unit. For example, asking students to develop their models independently before developing a consensus model as a class provides a basis for assessing individual student progress and prepares everyone for the work of developing a consensus model. Then, as the class develops the consensus model together, the teacher can partner with and support students to develop and refine the class' explanatory models of phenomena and solutions to design challenges.

Holistic Rubrics in Summative Assessment Keys

Summative tasks include a three-level rubric for holistically assessing students' responses across the different prompts in each of the three dimensions. The basic idea is that the growth of understanding over time depends upon building on students' existing ideas and ways of thinking. Through carefully guided sensemaking about phenomena and problems in the curriculum, students make connections among these different ideas. Storylines for units include multiple opportunities to make their thinking explicit, compare it to others, and put different pieces of knowledge together. As the rubrics indicate, students' knowledge becomes more connected and organized over time. The organization and restructuring of pieces of knowledge into a system is what characterizes expert understanding (diSessa, 2018). With a strong organization of core ideas and crosscutting concepts and a deep grasp of when and how to use science and engineering practices, students have the potential to explain many phenomena related to the ones they encounter in materials, and the rubrics allow a teacher to assess how well students can apply the pieces of knowledge they have developed and connected through the unit.

The titles used for the levels in rubrics are likely to be unfamiliar, but are used intentionally to disrupt deficit conceptions that students often internalize as labels that apply to themselves ("I'm a three," "I'm below basic").

The language in the rubrics leads with what students can do, grounded in the specifics of what is expected in the response. The lowest level of the rubric is never simply a list of things that are missing from a student response, though secondary phrasing will often clarify what might be missing that would be needed for a response to be at a higher level in the rubric.

Language in the rubrics is specific to the task (see example below), not generic to a DCI, SEP, or CCC. Rubrics avoid language such as "adequate," "appropriate," and "sufficient" common to many rubrics, as such language depends too much on teacher judgment, is difficult to use in grading, and gives students inadequate guidance for how to improve. Rubrics include sample student responses that fit in the category. For multi-prompt transfer tasks, the key identifies the prompt(s) where such responses might be found.

	Foundational Pieces	Linked Understanding	Organized Understanding
Meaning for tasks focused on **explaining a phenomenon**	Response draws on a range of everyday ideas and ideas encountered and observations made in investigations in responses	Response draws on a range of everyday ideas and ideas encountered in investigations **and coherently connect them together to explain some aspects of the phenomena**	Response draws on **elements from all three dimensions,** accounting for **all relevant aspects of data and investigations** (including potentially contradictory aspects), along with everyday ideas, to support an explanation of **all aspects of the phenomenon.**
Meaning for tasks focused on **designing a solution to a problem**	Response draws on a range of everyday design solutions and ideas and observations emerging from investigations to develop initial criteria and constraints for solutions based on their own priorities and values.	Response draws on a range of everyday design solutions and ideas emerging from investigations and **connects them to criteria and constraints that have been developed for solutions** from information and data provided in the task about stakeholders' priorities and values.	Response draws on **elements from all three dimensions,** accounting for **all relevant aspects of data and investigations** (including potentially contradictory aspects), along with everyday ideas, to support a solution that **satisfies all constraints and criteria** students have developed using information and data provided in the task about stakeholders' priorities and values.

Suggestions for Instruction Embedded into Rubrics

Below each rubric is guidance for the teacher with suggestions to support the growth of students' understanding. The suggestions in each rubric are specific to the content, but here are some general types of suggestions that may be provided:

If a student response shows **foundational ideas** and needs support in linking ideas, suggestions for instruction may include:	**If a student response** shows **linked** but not a fully organized understanding, suggestions for instruction may include:	**If a student response** shows a well **organized understanding** of the anchoring phenomenon, suggestions for instruction may include:
• Revisit the Progress Tracker to connect more of what they know and can do to build a more coherent explanation of the phenomenon • Ask students to consider how their own ideas link to investigations they have conducted and models they have constructed • Consider possibilities about how two ideas that have been explored might be connected	• Problematize students' existing thinking by posing a question that could help students identify a gap in their own thinking • Consider an alternative point of view that would lead them to pose new investigative questions • Invite them to integrate more from the investigations they have experienced and models they have constructed into their explanations or solutions	• Explore further connections to everyday life and their communities • Explore whether their knowledge generalizes to cases that are not obviously connected to the anchor phenomenon

Classroom Level Guidance for What to Do Next

Individual feedback to students may not be enough if too many students are struggling with the material. Below is guidance at the unit level that can be referenced any time a leveled rubric is used adapted from the Contingent Pedagogies Project (DeBarger et al., 2017).

If this happens in my class...	I can adjust instruction in this way...
If 75% or more of students provide expected responses during an assessment opportunity...	• Continue onto the next section; provide individual feedback to students who are struggling
If 50-75% of students provided expected responses during an assessment opportunity...	• Pair students up at random to discuss their thinking about the prompts. There is sufficient knowledge in the room that peers can support one another's learning. Following the pair strategy, students can be invited to share their thinking. • Listen in on the conversations and choose and sequence which students to share out who have the expected understanding.
If less than 50% of students provide expected responses during an assessment opportunity...	• Analyze the assessment items for which pieces of understanding are missing, to review or reteach • Pause to guide students through their progress trackers to review what they have done together and identify gaps in learning. • Re-teach by guiding the revision of an explanatory model, reviewing a difficult text or activity, or modeling a practice of making sense of data. One approach that could be helpful is for the teacher to engage in public sensemaking using a "think aloud" approach.

In OpenSciEd Physics Unit 5 *Microwaves*, students complete a transfer task, *Evaluating 5G Safety*, in Lesson 13. Question 4 of the transfer task asks students to respectfully critique and comment on a social media post using science ideas related to the electromagnetic spectrum. The Answer Key provides teachers with the following suggestions for instructions they can use depending on student understanding as outlined in the rubric:

	Foundational Understanding	Linked Understanding	Organized Understanding
Suggestions for instruction	If the majority of the class demonstrates a foundational understanding, spend some time analyzing the posts as a class, taking apart the evidence provided and comparing it against our Progress Trackers.	If the majority of the class demonstrates a linked understanding, ask students to work with a partner to go back to their Progress Trackers and look for evidence related to the information in the social media posts.	If the majority of the class demonstrates an organized understanding, challenge students by asking them to provide a critique to both posts. Ask students to search social media or the internet for claims being made about 5G and related technologies. Always encourage students to be safe online, and consult a school counselor and/or a technology professional before encouraging students to respond to anything directly.

Additional Support for Self and Peer Assessment

Peer Assessment

There will be times in your classroom when facilitating peer feedback will be very valuable for their three-dimensional learning and for learning how to give and receive feedback from others.
Peer assessment 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 peer feedback. For more resources to support peer assessment, see the Appendix.

Self-assessment

Throughout the curriculum you will find opportunities for students to engage in self-assessment. These opportunities provide students with a structure to reflect on their learning, community engagement and growth. These opportunities can be found after important discussions, investigations, and can be added anywhere throughout the unit. For more resources to support self assessment, see the Appendix.

Classroom Culture and Community

Purpose of Community Agreements

OpenSciEd materials rely on students collectively figuring out science ideas through productive discourse and classroom talk. This requires a classroom culture where 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 move all students' learning forward. The development and ongoing use of the following classroom community agreements can support safe and equitable student participation in collaborative sensemaking.

In OpenSciEd High School, guidance is provided to teachers to support the development and use of Community Agreements with their students. The term Community Agreements is used instead of the term norms to highlight that there is no "normal" way to collaborate. When done collaboratively and thoughtfully, developing Community Agreements is a powerful tool to support equity in the classroom. Be aware that terms such as safe, respectful, polite, nice, and kind are culturally embedded, and thus can mean different things in different communities. For example, one student may define kindness as not calling out a peer in public when they say something offensive. But another student may define kindness as being honest with peers, and sharing what is on their mind and heart right away. Whose version of kindness receives priority? When these ideas are not explored, norms can be used to police or silence justifiable hurt and anger, particularly from students who identify with marginalized communities.

When students engage in academically productive talk, they are asked to talk in ways they may not be comfortable with and may differ from how they participate at home or in other aspects of their communities. To help develop a classroom culture that supports academically productive talk, four key Community Agreements are used as a starting place in the first lesson of the first unit of each OpenSciEd High School course: respectful, equitable, committed to our community, and moving our science thinking forward.

Four Key Agreements

Community Agreements	
Respectful Our classroom is a safe space to share.	● We provide one another with support and encouragement. ● We share our time to talk. We do this by giving others time to think and share. ● We critique the *ideas* we are working with but not the *people* we are working with.
Equitable Everyone's participation and ideas are valuable.	● We monitor our own time spent talking. ● We encourage others' voices that we have not heard yet. ● We recognize and value that people think, share, and represent their ideas in different ways.

Committed to Our Community We learn together.	● We come prepared to work toward a common goal. ● We share our own thinking to help us all learn. ● We listen carefully and ask questions to help us understand everyone's ideas. ● We speak clearly and loud enough so that everyone can hear.
Moving Our Science Thinking Forward We work together to figure things out.	● We use and build on others' ideas. ● We use evidence to support our ideas, ask for evidence from others, and suggest ways to get additional evidence. ● We are open to changing our minds. ● We challenge ourselves to think in new ways.

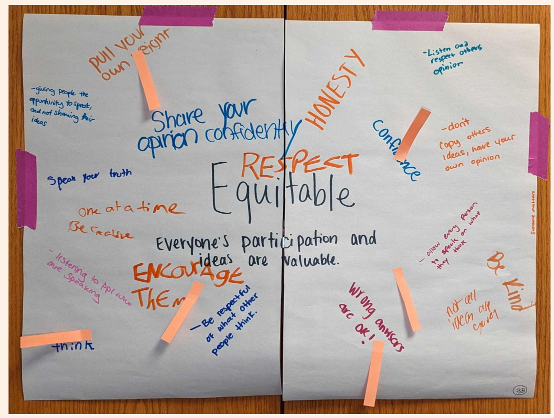
Respectful: Our classroom is a safe space to share
In order for students to be willing to take the risks as they make sense of complex ideas with their peers they need to feel safe and know that they will not be ridiculed or mocked. Establishing and enforcing Community Agreements that work to make the 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 elements that can support respect.

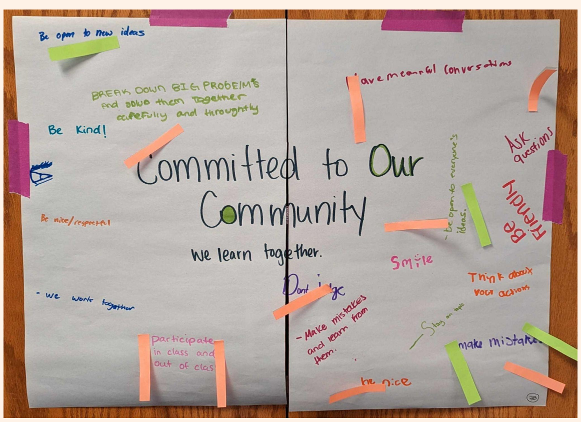
Equitable: Everyone's participation and ideas are valuable
In order to highlight the importance of discourse in helping the classroom figure out science ideas together, *all* students need to have access to the conversation. This does not mean that every student has to talk during every discussion, however 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. Community Agreements to support equitable discussions include monitoring our own time spent talking, encouraging others' who we have not heard from, and recognizing and valuing that people think, share, and represent their ideas in different ways.

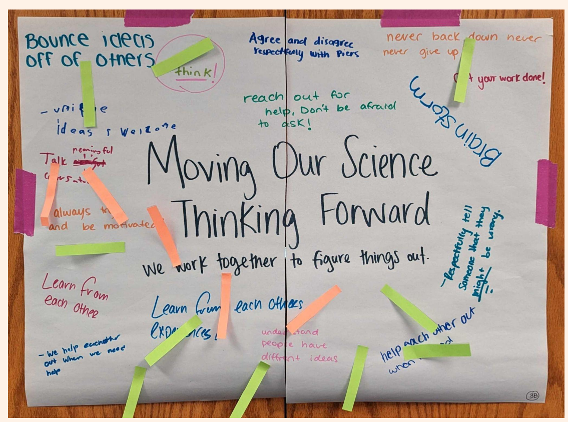
Committed to Our Community: We learn together
A goal of the classroom should be working to "get smarter together". It is not enough for students to share ideas without connecting to others' ideas. Establishing this Community Agreement highlights the importance of being prepared and focused during discussions. Creating a classroom culture where there is a collective responsibility to the learning community to come prepared, share everyones' thinking so that others can understand, listening carefully and asking questions works to help all students make sense of phenomena. Teachers should encourage students to contribute ideas even when they are not sure, because as part of a community, they can work with others to support their ideas.

Moving our Science Thinking Forward: We work together to figure things out
We engage in these academically productive discussions in order to deepen our understanding and make sense of complex science ideas. These discussions are focused on using evidence and reasoning to move thinking around science ideas forward. Incorrect 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 Community Agreements around asking questions and working

together to move the group's science thinking forward. Students need to practice how to use and build on others' ideas, the importance of providing and asking for evidence, encouraging others to clarify their reasoning, and being open to changing their minds based on new evidence. Teachers and students can practice with prompts such as: *Why do you think that?* to move beyond considering the question a challenge and thinking about it as an opportunity for growth.

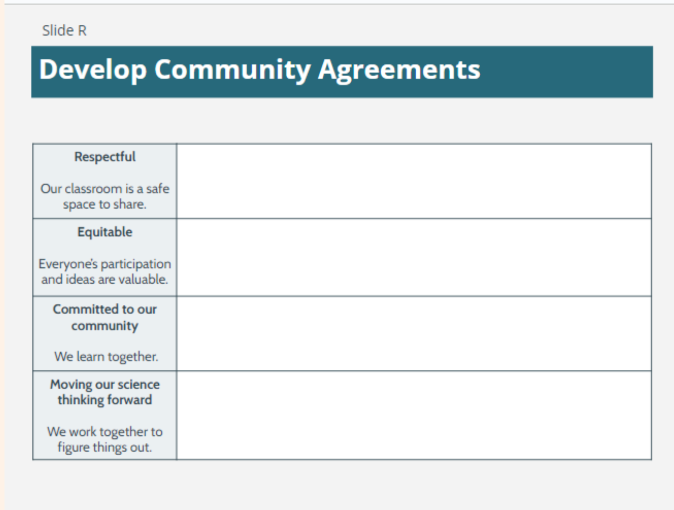






Development of Community Agreements is embedded into the first unit of each OpenSciEd HS course. Many subsequent lessons refer to the Community Agreements and students have an opportunity to revisit them, revise and/or add to, and reflect on how the class is using them.

For example, in Lesson 1 of OpenSciEd Chemistry Unit 1 *Polar Ice*, students begin to co-construct the Community Agreements as a class using the following slide for guidance:



At the end of the first lesson, students reflect on how well they are adhering to these Community Agreements using differently colored pieces of paper. The sample classroom images above illustrate students' reflection on how well they think the class has done with specific Community Agreements. The green papers show agreements students think the class is doing well with, while the orange papers are those they feel should be improved upon.

Another example of a class using sticky dots to indicate their progres is shown below:

A natural time to revisit Community Agreements is before whole class discussions and before working or carrying out investigations in small groups. Opportunities are also provided for the class and individual students to assess how well they are adhering to and if any revisions should be made to the Community Agreements.

The table below provides examples of some, but not all, moments when the Community Agreements are revisited during the OpenSciEd HS chemistry course. It is also important to note that as students progress throughout the course, there is reduced scaffolding around how students engage with the Community Agreements.

<table>
<tr><th>When does it occur?</th><th>How is it shown in the Teacher Guide?</th></tr>
<tr><td>Unit 1, Polar Ice Lesson 2</td><td>Say, I have data that might be able to help us. First though, we want to make sure we are sticking with our community agreements throughout the unit. Today, we will focus on the agreements we made around being "Respectful." Show students the community agreements and elicit reminders about how the class decided to act to show respect.✱</td></tr>
<tr><td>Unit 1, Polar Ice Lesson 3</td><td>Establish "Equitable" as a focal agreement. Display the Community Agreements and elicit suggestions on how we can conduct this investigation in an equitable manner and how the roles can help in doing that.</td></tr>
<tr><td>Unit 1, Polar Ice Lesson 4</td><td>Say, In this lesson, we are going to do some important work as we think about these changes. We need to rely on each other to move our thinking forward, because there will be lots of little ideas to consider. Indicate the Community Agreements and elicit students' ideas for how we can work on the focal agreement of "Moving Our Thinking Forward."</td></tr>
<tr><td>Unit 1, Polar Ice Lesson 5</td><td>Introduce the discussion mapping tool. Have students meet in a Scientists Circle and explain that we will be participating in a Consensus Discussion about what we think we know about the proposed solutions. ✱ Say, In a Consensus Discussion, we will press toward a common explanation or model. We will try to resolve disagreements and different perspectives to take stock of where we are in our "figuring out." At the end of our discussion, we might have new questions to investigate next. Ask students which two focal community agreements they think will be important to balance for this discussion. Students will likely say respect and moving our thinking forward. If the class suggests other community agreements and is in agreement on why they are important, adopt those as the focus for this discussion instead. ✱

Revisit community agreements to support upcoming investigations. Display slide W. Say, We have these shared community agreements that we created as a class. How can these agreements support us as we work together in upcoming investigations? ✱

Direct students to turn and talk about which agreements they think we can rely on to support our class community through future investigations. Listen in on partner discussions. Then, invite students to share their ideas with the class.</td></tr>
<tr><td>Unit 2, Electrostatics Lesson 4</td><td>Prepare students to give each other feedback. Display slide B. Explain that scientists often use feedback to sharpen their ideas. Reference the Community Agreements and tell students that in this lesson we will focus on being committed to our community. Highlight particular agreement language that emphasizes that one part of being in a community is providing honest, constructive feedback to one another. Remind students that the goal is for everyone's ideas to be pushed a little bit so that we can make more progress as a class.✱</td></tr>
<tr><td>Unit 2, Electrostatics Lesson 9</td><td>Have students complete an individual reflection about community agreements. Display slide L. Direct students to the electronic survey you shared with them (you can make a copy of the form linked at https://docs.google.com/forms/u/3/d/1tE9iCtSMeG2D62k83q8FEpQeC4qaychwwFOToiJ62fw/copy). Explain to students that their thoughtful responses to these prompts will help gauge how we are doing as a classroom community.✱</td></tr>
<tr><td>Unit 3, Space Survival Lesson 2</td><td>Revist Community Agreements. Say, During our next investigation, you and your group will only visit two of the seven stations. This means that you will need to work with your group to effectively communicate the information you figure out with the rest of your classmates in a short period of time.

Present slide F.

<table>
<tr><th>Suggested prompt</th><th>Sample student response</th></tr>
<tr><td>What are some of the challenges and needs we should consider in such work?</td><td>It will be hard to share everything.

We will need to make sure that everyone understands what we investigated.

We will need to communicate well with our group and the rest of the class.</td></tr>
<tr><td>Which Community Agreements would best support us in meeting those challenges and needs?</td><td>Accept all responses.</td></tr>
</table>

Present slide G. Distribute Focal Community Agreement. Give students a few minutes to complete the three pre-investigation questions on the handout where they choose a focal community agreement to work on today and describe how they will enact it. Students will use this later as a self-assessment opportunity. ✱</td></tr>
</table>

Unit 4, Oysters Lesson 1	**Commit to a focal community agreement.** Post the previous community agreements. Display **slide K**. Ask students to think about one community agreement they would like to work on during this unit. Have them share with a partner and invite their partner to remind them about their commitment.
Unit 5, Fuels Lesson 11	**Revisit Community Agreements.** Have the Community Agreements visible. Say, *In a minute you will share your exit ticket arguments with a few of your classmates. You may not have come to the same agreements as each other, so let's take a moment to remind ourselves of our Community Agreements.* Present **slide N**. Say, *Look over the Community Agreements. Which community agreement should we make sure we are following when sharing and discussing our exit ticket arguments?* Accept all student responses and encourage students to show when they agree with their classmates. Say, *If we are following that community agreement, what would respectful disagreement sound like?* ✱ Accept all student responses.

Attending to Equity

OpenSciEd units are designed to promote equitable access to high-quality science learning experiences for all students by offering students diverse entry points, experiences, and scaffolds. OpenSciEd units intentionally support equitable learning through the following design features:

Learning is relevant and meaningful to students and their communities. OpenSciEd High School units are designed to connect instruction to the interests, identities, and experiences of students, and to the goals and needs of their communities. To achieve this goal, phenomena must be interesting and accessible to students. Anchoring phenomena were chosen from a group of phenomena aligned with the target performance expectations, gathered by a team of designers, teachers, and content experts. From this carefully selected group, designers developed and administered surveys to thousands of students across the country. The final phenomena were selected based on the results of these surveys, and in consultation with external advisory panels that include teachers, subject matter experts, and state science administrators. Phenomena were prioritized when surveys and conversations with regional administrators and teachers indicated that they had high relevance to students' everyday experiences and communities. Many units include phenomena that connect directly to problems and disparities that students care about in their communities, such as sea level rise, reliable electricity production, or vehicle fatalities.

Learning center the interests and experiences of students to whom are owed an educational debt. Anchoring phenomena have been chosen using a process that centers the interests of students from populations that are underrepresented in science, technology, engineering, and math (STEM). Survey results were disaggregated by racial identity, gender identity, and school context (urban/suburban/rural), and these factors were weighed in decision-making. While OpenSciEd HS is designed to privilege the interests of students to whom we owe an educational debt, we must not essentialize minoritized groups by assuming that a trend in the data equates to homogenous interests and experiences. Providing a diverse suite of entry points into content and practices creates more opportunities for every student to connect with the content. Thus, designers took care to choose phenomena across a course that were meaningful in different ways, and at different scales, with the result being a diverse suite of entry-points into the content, from the everyday (using a microwave oven), to the societally relevant (rising cancer rates in certain communities), to the futuristic (exploring the possibility of living on Mars).

Units include opportunities to make connections. Throughout every OpenSciEd HS unit, there are opportunities built in to encourage 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 class and community's understanding. In addition, many units include explicit moments for students to bring in the expertise, experiences and values of friends, families, or community members. For example, in OpenSciEd Physics Unit 1 Electricity, students interview a trusted adult about what they value when it comes to energy production, and use these conversations to develop criteria and constraints to complete a design challenge.

Units support equitable sensemaking. Collaborative sensemaking (or "figuring out") plays a central role in the OpenSciEd units and provides opportunities for students with diverse assets and perspectives to contribute meaningfully to the intellectual work in the classroom. As described in the Supporting Classroom Discourse section, discussion and discourse are essential features of the OpenSciEd units. Scientific language is developed through engagement in scientific practices, motivated by student's desire to answer their own questions. This means that language is used across multiple modalities, registers, and interactions. Teachers should encourage students to express their ideas in language and styles they are comfortable with in order to open the conversation and sensemaking to all students. The OpenSciEd units intentionally incorporate time for teachers to develop and foster classroom norms that provide a safe learning culture. Classroom discourse supports students in developing, sharing, and revising their ideas, and specific strategies are included to support emergent multilingual students.

Units incorporate culturally responsive and sustaining practices. The OpenSciEd 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 explicitly valued and central to the storyline development of a unit.

Units support an expansive view of learning through formative assessment. Opportunities to assess student thinking are embedded throughout the units (see the Assessment System section for more information). These opportunities are designed to enable teachers to observe students' authentic reasoning and scientific ideas. At numerous points in a unit, students demonstrate understanding 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 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.

To highlight the equity features in lessons and provide additional guidance to teachers, "Attending to Equity" callout boxes are included in the teacher guides. These callouts provide specific and just-in-time support.

In OpenSciEd Biology Unit 1 *Serengeti*, the class revisits the Community Agreements prior to engaging in a discussion about wildebeest data. There are two "Attending to Equity" callout boxes that provide additional reminders and strategies to foster participation from all students.

9 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION ABOUT WILDEBEEST CARRYING CAPACITY

12 min

MATERIALS: *Serengeti Kinesthetic Model*, Community Agreements (from Lesson 1)

Revisit Community Agreements to support upcoming discussions. Display **slide M**. Say, *We have these shared Community Agreements that we created as a class. How can these agreements support us as we work together in upcoming discussions?* ✱

Turn and talk about Community Agreements. Direct students to turn and talk to a neighbor about which agreements they think we can rely on to support our class community through future discussions. Listen in on partner talk. Then invite students to briefly share their ideas with the class.

Begin by discussing the wildebeest data. Display **slide N**. Have students turn and talk to get their ideas flowing before a whole-group discussion. Ask, *What are some initial noticings you and your partner had about the wildebeest population data?* Listen for students to say things such as: *When we look at the populations of the wildebeest over time, we notice big changes in the wildebeest population.* ✱

Lead a Building Understandings Discussion about the relationship between the wildebeest population and grass. Display **slide O**. Gather the class in a Scientists Circle with *Serengeti Kinesthetic Model* and *Wildebeest Population Data*. ✱

Use the "Key Ideas" box and prompts below to facilitate this discussion. Work with the class to use their data to show what is happening as students share. You might have students stay seated, stand and hold *Serengeti Kinesthetic Model* or *Serengeti Kinesthetic Model* up, tape them to the wall or board, put them under a document camera, or even lay them on the floor of the circle.

KEY IDEAS

Purpose of this discussion: To establish that the wildebeest population size is limited by the amount of food available. The wildebeest population can only reach a certain number before the population decreases and then fluctuates around that point (carrying capacity), going up and down slightly. Following this discussion, students will co-construct a definition for carrying capacity.

The discussion is structured to help students use evidence from the data in the graphs and rates of change to support their arguments.

Listen for these ideas:

- See the responses below and *Wildebeest Population Data*.

Suggested prompts	Sample student responses	Follow-up questions
How did the historical data compare to the data we collected and analyzed from the kinesthetic model?	The actual data for wildebeest populations looked very similar to the data we collected in the simulation. Both sets of data increased rapidly at first and then reached a high point. In the next few years, the population went	

✱ ATTENDING TO EQUITY

Building classroom culture: This is an important opportunity to emphasize that each individual has contributions to make to their community of learners. It is through differences in thinking that the class will grow their knowledge together. Throughout the rest of this unit, students engage in discussions to make sense of how what they have figured out about the Serengeti influences their conservation profiles. Being open to sharing knowledge products that depict their current thinking and listening to classmates who share their knowledge will help move the community's understanding forward.

✱ ATTENDING TO EQUITY

Universal Design for Learning: It is important to organize activities in ways that create opportunities to support student *engagement* in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). This is especially beneficial to emergent multilingual students. For this reason, partner talk or small-group talk should precede whole-group discussion whenever possible to give students an opportunity to share their ideas with one or two peers before going public with the whole class. Throughout this unit, there will be instances in which the students immediately engage in whole-group discussion. Insert a partner talk prior to the whole-group discussion if you believe this would benefit your students' ability to communicate and *express* their ideas.

Universal Design for Learning (UDL) Principles

The Universal Design for Learning (UDL) Guidelines can be used to design learning experiences that meet the needs of all learners (CAST, 2018). The UDL guidelines informed the design of the OpenSciEd instructional materials to minimize barriers and create pathways for all learners, particularly those who identify with cultural and linguistic communities that have historically been underserved in science education. The table below highlights the guiding principles and corresponding guidelines. For more details, including checkpoints, please visit the CAST website.

UDL Principles are Embedded in OpenSciEd Units

As outlined in the table below, the OpenSciEd High School units are purposefully designed with multiple avenues for the three guiding principles of UDL - *engagement, representation*, and *action and expression:*

Provide multiple means of *Engagement* *the "WHAT" of learning*	Provide multiple means of *representation* *the "WHY" of learning*	Provide multiple means of *action and expression* *the "HOW" of learning*
In OpenSciEd High School:		
• 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 on their Progress Trackers, **maintaining student investment** in the work of figuring out the phenomena. • Lessons provide guidance for developing a **safe space for students** to share and build on ideas through developing and revisiting communication norms.	• Digital materials encourage students to access technology tools to support learning (e.g., text-to-speech). • Lessons incorporate models, data tables, graphs, and charts. • Concepts are presented in multiple formats (videos, podcasts, diagrams, models, images, text) • Students co-develop definitions and create personal glossaries. • Students create and revise models to visually represent concepts and big ideas. • Students apply their background knowledge to connect to, explain, and ask questions about phenomena and problems. • Lessons provide supported opportunities to generalize learning to new phenomena or problems.	• Students are encouraged to use multiple formats to express their developing understandings and to show their learning on formative and summative assessments. • Lessons encourage students to plan, model, and revise their thinking. • Classes monitor progress and synthesize learning through the DQB, Navigation Routines, and Putting the Pieces Together Routine. • Lessons include self-assessment opportunities, student-facing tools like discussion protocols, and self-assessment rubrics which support students to plan for and self-evaluate their learning and growth across the unit.

		• Teacher guides feature callout boxes with further guidance for diverse populations.

Specific Examples of UDL in OpenSciEd lessons

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). OpenSciEd units use an anchoring phenomena that is complex and interesting in order to both stimulate and maintain student engagement throughout each unit.

For example, in OpenSciEd Physics Unit 1 *Electricity*, students learn about the 2021 Texas blackouts. Students are provided multiple avenues to engage as they explore the phenomenon. They collect firsthand accounts, dissect a power strip, develop and revisit a class DQB, develop and test models, listen to a podcast with a scientist, learn about the inequitable impact on people in communities where there are existing disparities, and develop a plan for improving our community's energy infrastructure.

Collecting Stories

Ask your friends and family if they have ever experienced a blackout. If so, what was it like? What do they think caused the blackout?

Interview at least 1 person besides yourself. Keep track of your interviewees' ideas here, or on a separate piece of paper, to put in your notebook. If you have experienced something like this and feel comfortable sharing it with your class, record your own story as well.

Interviewee's name:

Notes:

Representation

OpenSciEd units require students to use science concepts to figure out explanations or solutions to natural phenomena. The way content is provided or presented to students can enhance a learner's ability to engage in rich discussion and thinking. Representation focuses on what is presented to students to engage with the intended goals of learning.

In OpenSciEd Chemistry Unit 1 *Polar Ice*, the *Thawing Permafrost* transfer task asks students to apply their understanding of feedback loops in Earth systems to predict the effects of permafrost thaw. To gain context and background knowledge about permafrost, students watch a video about the thawing of permafrost, view images of the impact of permafrost thaw, and examine a model that shows the impacts of permafrost thaw.

Thawing Permafrost

Much of the surface in and near the Arctic that is not ice-covered is covered by a mixture of soil and ice. This mixture is called *permafrost* because, historically, it did not thaw during the summer and remained permanently frozen. Today, however, it is beginning to thaw, as you will see in the video : https://youtu.be/a_d3uqoYxRO.

Part 1a: What did the video show? What does it remind you of?

Permafrost thaw is a major problem because it impacts other Earth systems in possibly harmful ways, similar to polar ice melt.

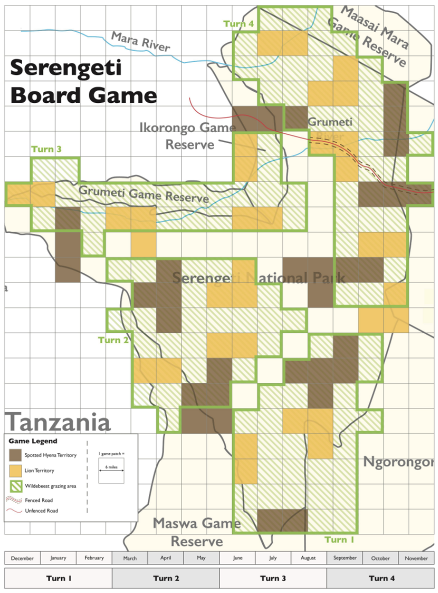
When permafrost thaws, land can change drastically, among other effects. The table below lists some of the effects of thawing permafrost the Earth has experienced already. How will Earth be impacted as permafrost continues to thaw? Answer the questions below.

 Pixabay  David Mintz, CC BY 3.0 Burrowing animals and birds that nest on slopes lose habitat as burrows and slopes collapse.	 Adam Jones, Ph.D., CC BY 3.0 Buildings warp and become unusable, like historic St. Andrew's Presbyterian Church in Dawson City, Yukon, Canada. Modern buildings are also impacted, unless they are built with special, more expensive design features.	 USGS, B. Jones Permafrost contains carbon dioxide, which has been trapped for thousands of years and can be released as the permafrost thaws.

Action and Expression
The goal of the Action & Expression principle is to ensure that learners can fully communicate what they know through varied forms of action or expression. The OpenSciEd 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.

In OpenSciEd High School Biology Unit 1 *Serengeti*, students play a board game in Lesson 7 to explore the relationships between predators and prey in the Serengeti National Park ecosystem with the goal of understanding how group behaviors support the survival of species and how computational modeling can support scientists in making sense of complex systems.

Serengeti Game Board



A small group of wildebeest grazing in an area where the grasses are short and allow them to easily spot predators. **Move one of your small group wildebeest tokens up to 3 spaces away from a predator token.**

Muhammad Mahdi Karim, GNU 1.2

UDL and Differentiation

The principles of Universal Design for Learning are built into the design of OpenSciEd units to provide equitable and accessible learning. We acknowledge that teachers will still need to find ways to accommodate activities to fit with student learning needs or the needs and resources of the classroom. There are many ways differentiation occurs in classroom settings. Teachers can make adjustments in terms of the content, learning processes, and student products in order to address their students' readiness, interest, and special learning needs (Tomlinson & Allan, 2000). OpenSciEd units are also designed with differentiation in mind, allowing teachers to adapt the materials as necessary without diminishing the learning experiences for students.

OpenSciEd units specifically include differentiation strategies and information about adapting the content, process, or product of the lessons in the following sections:

- Teacher background knowledge
- the lesson-level "Where we are going" and "Where we are not going" sections
- the assessment overview and guidance tables
- home letters

Teachers can also find differentiation guidance in the teacher guides in three particular types of callouts:

- **Equity** callouts focus on moments in instruction in which certain students may benefit from a particular strategy, for example, 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 and/or completing different learning activities based on student progress. These can be particularly helpful for students with high interest or for students or classrooms that need to modify the unit based on availability of time or access to resources.
- **Additional Guidance** callouts provide more specific instructions to teachers about how to make a

learning activity successful based on their students' needs. The callout boxes provide a variety of instructions to modify the timing, grouping, or resources for a particular activity.

In OpenSciEd High School Biology Unit 4 *Urbanization*, students are encouraged to choose a location in which to study selection pressures in Lesson 4. An option for a class exploration is also provided.

2 · EXPLORE UCSD CAMPUS AND MOUNT LAGUNA 12 min

MATERIALS: computer with internet access, *Exploring Juncos' Environment*

Explore the UCSD campus and Mt. Laguna. Say, *Let's start by exploring the two environments to see if we can get any ideas about selection pressures.* Display **slide F.** Distribute *Exploring Juncos' Environment* to every student. Introduce students to using Google maps and explain that they will work in pairs with one student exploring the UCSD campus, while the other explores Mt. Laguna. Students should follow the instructions on the slide and the handout as they look for evidence of selection pressures that could cause bold juncos to survive better in the urban environment. After students explore their assigned location, direct them to share and record their findings with their partner. ✱

ALTERNATE ACTIVITY If the class is limited on time, conduct the virtual explorations as a class, allowing students to complete *Exploring Juncos' Environment* as the teacher navigates to the locations. If students want to see how bold birds behave, replay https://youtu.be/JslBVIo13qc .

Discuss connections between selection pressures and boldness at the UCSD campus. Display **slide G**. Facilitate a discussion of what students figured out from the exploration using the slide prompts.

✱ ATTENDING TO EQUITY

Universal Design for Learning
Allowing students to choose specifically where they explore within these two different environments provides and supports student ownership of their learning. Students are able to *engage* in the activity using their own interest and ideas by giving them choice, access, and control in this investigation.

Supporting Emerging Multilingual Learners

Who are emergent multilingual learners (EMLs)?

We intentionally use the term emergent multilingual learner (EML) because it is asset-oriented, highlighting students' multiple resources and knowledge of languages in addition to English. An estimated 5 million students, or 10% of the total student population in the United States, are EMLs. And this is likely an underestimation because these numbers only reflect students who have been legally identified as English Language Learners (ELLs) and thus are entitled, through state and federal laws, to academic coursework with specialized support to help them reach certain thresholds for English proficiency. Students identified as EMLs make up an incredibly diverse group. These students come from a constellation of intersecting identities along the dimensions of race, culture, 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.). Consequently, EMLs bring rich linguistic and cultural resources into classrooms, including valuable lived experiences and ideas about how our natural world works. Because EMLs have historically received unequal access and inadequate instruction in science, it is critical that teachers learn to notice, value, and leverage their contributions in the classroom.

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

To meaningfully engage in authentic scientific practices such as modeling, argumentation, explanation, and questioning as called for by the NGSS, students must use language in increasingly complex ways. These SEPs require the use of various linguistic (e.g., speaking and writing) and non-linguistic (drawings, graphs, models, gestures) forms of communication. Adding to this complexity, 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 groups' understanding of the topic being explored. These language demands present opportunities for EMLs to tap into their linguistic resources for sensemaking, but only if we set them up for success.

How is language used for scientific sensemaking?

When considering how to support 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. 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. For example, 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. But 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 for details).

Phenomenon-driven science instruction provides EMLs with authentic contexts and purposes for which to use developing language(s) and supports students with 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 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 OpenSciEd support EMLs?

There are two primary ways that OpenSciEd supports EMLs: 1) through the curricular design and pedagogical routines that are at the heart of the instructional model, and 2) through callout boxes embedded in the teacher materials. The curricular design and routines of OpenSciEd grounds students' learning experiences in real-world phenomena. For instance, a unit on lightning is anchored in students figuring out - *What causes lightning and why are some places safer than others when it strikes?* In this approach to science learning, students are not just memorizing science ideas or "facts" about energy transfer and electrostatics, but instead are working with peers to figure out their own understanding of - and even designing their own solutions for - real problems that occur in our natural world. When the phenomena being explored are relevant, meaningful, 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 OpenSciEd instructional model - including the Anchoring Phenomena Routine, Investigation Routine, Problematizing Routine, and Putting the 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 non-linguistic modes of communication. OpenSciEd teacher materials also include callout boxes with a range of suggestions for supporting EMLs, from suggesting particular ways to group students to unpacking the meaning of certain words in the context of science. These callouts help teachers see why these instructional moves are important, and provide additional in-time support

Supporting Classroom Discourse

The negotiation and construction of scientific ideas through talk is a central part of the program's vision. In OpenSciEd, discussion is the glue that connects science and engineering practices to one another, and it connects those practices to disciplinary core ideas and cross-cutting 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. In OpenSciEd, we build 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, Michaels, Moon, et al., 2017).

OpenSciEd 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.

Types of Discussions

Initial Ideas Discussion- *when students are beginning the process of making sense of a phenomenon*

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 to share and make sense of ideas-even if those ideas are tentative or still being formed

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 about 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 - *when students have been exploring new ideas*

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

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 which has thus far been gathered and made sense of.

Consensus Discussions - *when students have had the opportunity to construct new understandings*

Purpose

- To collectively work towards a common (class-level) explanation or model. This 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
- Take stock of where the class is in its figuring out and support the public revision of earlier ideas

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, disagrees, has alternatives, or 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.

Since each type of discussion serves a different purpose, there are some places in the navigation routine where each type of question most commonly occurs, though they can be used at any point.

OpenSciEd Navigation Routines					
	Anchoring Phenomenon	Navigation	Investigation	Putting the Pieces Together	Problemitizing
Initial Ideas use any time students are beginning the process of making sense of a phenomenon	*		*		*
Building Understandings use any time students have been exploring new ideas		*	*	*	
Consensus Discussions use any time students have had the opportunity to construct new understandings				*	

Questioning Strategies to Support Discussions

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. To engage students in these types of discussions, OpenSciEd 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) eliciting questions, (2) probing or clarifying questions, (3) challenging questions, and (4) questions to support science discourse.

Eliciting 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 *eliciting questions* include:

- 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?

Probing or Clarifying 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 his or her 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 *probing or clarifying questions* include:

- 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?

Challenging 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 *challenging questions* include :

- 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?

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 :

- Did anyone have a similar question to that?
- Does anyone have a different question that we haven't talked about yet?
- Can anyone add onto 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, challenge those ideas in productive ways, and 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 become an observer of student talk with one another, noting the progression of student thinking and areas where disagreement still exists, allowing the teacher to plan for future instruction. In OpenSciEd High School, opportunities are provided for teachers to support students in practicing and reflecting on the quality of their discussions.

Seven Ways to Encourage Equitable Participation 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:

- **Write and Pass:** 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.

- **Most Pressing Questions:** 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 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 Like a Coach:** 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 a scientist 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 side line. Then we'll switch, and you'll get a chance to share your ideas as you are coached by your partners."

- **Sentence Starters:** 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).

- **Gallery Walk:** 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.

- **Think-pair-share:** 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 to share, to listen, to be heard, and for their ideas to be represented and used to further the classroom community's developing understandings.

- **Convince Me:** 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.

Using a Scientists Circle for Equitable Discussions

What is a Scientists Circle?
A Scientists Circle reconfigures the learning space so students sit in a circle and can see and speak directly to each other. While it can be convened at any point in a lesson, it is most often used at moments in which the class needs to work towards consensus on ideas they have figured out. It is often important to also have access to whiteboards or chart paper to capture ideas the class agrees upon and also ideas they still have questions about.

How does a Scientists Circle support equitable science classrooms?
The physical arrangement of the classroom must change to shift whose voice and what ideas are valued in discussion. If the class is arranged with all the desks facing forward, then the emphasis is more likely to be on the teacher as the sole source of knowledge. This structure can discourage students from interacting with one another. This type of discussion presents a narrow view of what it means to do science. Changing this physical arrangement of the classroom (with students seated facing one another in a circle) coupled with utilizing moves that shift the authority of the classroom (e.g., Talk Moves or asking a *student* to publicly record the ideas the class is agreeing on, etc.) can lead to more opportunities for students to make meaning collaboratively, through talk. While forming a circle can be challenging (i.e., physically rearranging the chairs in a small space, taking up valuable instructional time), this physical shifting can make listening to each other and building upon ideas easier, and it can foster a sense of accountability to the group in a way that cannot be achieved when students are positioned throughout the room not facing each other. This shift is key when building a culture in which students are positioned as 'knowers' and 'thinkers' and the students and teachers work together to figure things out.

How is a Scientists Circle used in OpenSciEd materials?
Within the units, Scientists Circles are often convened at the outset of the unit, when students are developing an initial classroom model or artifact. Then, in other lessons within the unit, Scientists' Circles are embedded at key points for building understanding or working toward consensus. The allotment of time for this activity is typically 20 minutes or longer, to allow for physical rearrangement of chairs and then time to discuss and collaboratively figure out ideas.

Within the first units of each grade-level sequence, there are callout boxes to highlight the value of a Scientists Circle and how it can be arranged.

In OpenSciEd High School Biology Unit 4 *Urbanization*, students conduct a scientists circle in Lesson 1 to synthesize their learning from individual models, readings, and their science notebooks. Through their discussion summarize case studies and discuss similarities and differences.

SCIENTISTS CIRCLE

Your students may be familiar with the Scientists Circle from a previous unit. You will form a Scientists Circle in this lesson and many future lessons. Setting up the Community Agreements and logistics for forming, equitably participating in, and breaking down that space is important to do now if this is your first time forming such a space. Having students sit in a circle so they can see and face one another can help 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 routine to help students take on greater agency in steering the direction of their learning. This circle will also help students 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.

Discussion Tools

The OpenSciEd High School materials incorporates the following discussion tools into the teacher materials across Biology, Chemistry, and Physics:

1) The Discussion Planning and Reflection tool supports teachers as they intentionally plan, facilitate, and reflect on key instructional moments in the classroom. It is not intended that this tool be used for every discussion; rather, it can be applied to one or two moments within a unit where discussion is particularly beneficial for advancing the storyline.
2) The Discussion Mapping tool allows teachers or students to keep track of class-level patterns in participation. The completed discussion map can be a powerful source for class reflection and conversation about participation.

Supporting English Language Arts (ELA)

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.

Lessons are designed to support the Common Core State Standards for ELA (CCSS ELA). Across courses and lessons, students analyze texts using strategies drawn from *Common Core State Standards*.

Emphasis on Communication

Students are frequently engaged in speaking, listening, and responding to others as they participate in scientific and engineering practices. Students engage in peer-to-peer discussion to share, express, and refine their thinking. 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 the Discussion and Peer Feedback sections for more resources.

Embedded Features to Support Literacy

Purposeful Incorporation and Selection of Texts
The texts in the units have been carefully selected or adapted for the high school classroom, with attention paid to clarity of writing and key vocabulary. In some cases, readings have been written specifically for the lesson. A range of nonfiction genres is represented, including newspaper articles, science journals, essays, video transcripts, and more.

Students are prepared to access challenging text by engaging in prior thinking as a class and having a "reader's question" in their minds as they begin reading. This is closely aligned with many secondary content-area reading strategies, especially reading for author's purpose and determining the main goals of the text (e.g., Common Core State Standards, 2012).

Just as the texts themselves are purposefully selected, so is the placement of the texts. Text is featured 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. Some text is just-in-time to help the storyline move 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.

Sensemaking and discourse
Through OpenSciEd HS units, students are deeply investigating, modeling, and explaining complex scientific and engineering problems. Students experience a concept in some way prior to reading about it, allowing them to make a connection between the scientific information in the text and their personal experience of a concept. As Shrivedecker & Fries-Gaither (2017) explain, "Students need experiences that they can build on

as they read. Combining the inquiry investigation and the nonfiction reading helps students construct the desired science knowledge. Students gain experience and then build expertise" (p. 3). Reading practices benefit from this direct experience.

Often, before reading or responding in writing, students engage with a partner, small group, or whole class conversation to grapple with ideas. This discourse carries over to discussion and sensemaking of the texts, supports reading comprehension, and makes the writing process easier.

Multiple Modalities
Throughout the units, there are many opportunities to model ideas in words, pictures, and/or symbols. Engaging in this thinking before reading and writing prepares students of all levels to understand key concepts, identify questions, and synthesize their ideas.

Embedded Features to Support Diverse Learners and Readers

Attention to Reading Levels
To address the wide range of learners in classrooms, the reading levels of texts have been carefully considered. Depending on the reading level and the purpose of a given text within a unit, various supports are provided.

A target Lexile score (LS) of 1010-1200 is used for all courses. The median of this range corresponds to the middle of year (MOY) 9th grade based on "the text complexity grade bands in the Common Core State Standards for English, Language Arts" ("Prepare for College & Careers", 2020). If a text is above LS 1010-1200, specific reading comprehension or instructional strategies are suggested to support readers.

Additionally, the purpose of the text in each lesson has been considered. Some lessons target a lesson-level Performance Expectation (PE) that includes Science and Engineering Practice (SEP) 8. If students are engaging in SEP 8, multiple literacy supports are provided. This could include, but is not limited to, utilization of a specific reading comprehension strategy, a callout for differentiation suggestions, or additional text features to support accessibility. See below for more information.

Text features
All texts, regardless of reading level, contain features designed to increase comprehension. You'll notice that many readings include one or more of the following features to assist students in identifying key elements:

- **Titles, subtitles, and other section names:** Titles highlight the purpose of the text and "set the stage" for students to make conceptual connections to the text. Students can use their background knowledge and cultural funds of knowledge to connect with the reading right away.
- **Language register**: Science articles can take on different registers of language depending on the audience and purpose. Articles written for youth may have more colloquial language, while articles written for professionals will have more highly specialized language. While specificity is important, it should not come at the expense of general comprehension for any audience.
- **Images & graphics:** There is a reason "a picture is worth a thousand words." Images help readers engage with the text on a sensory level before the reading activity begins. An image that is closely

related to the text's main content can activate sensemaking that includes students' previous experiences, cultural funds of knowledge, and their curiosity.

- **Short sentences and paragraphs:** If a reader has to decode a lot of words in a sentence, it is hard to remember the concepts from previous parts of a sentence to string together. One way to alleviate this is with shorter sentences that maintain the meaning of an idea or paragraph.
- **Numbered lists:** Numbered lists with succinct titles help readers quickly gather the main idea of the text to come. Short online readings frequently use this feature. Lists are not just for struggling readers; they help everyone get the main ideas quickly.
- **Interactive features:** Online reading has the advantage of including interactive features in addition to text, such as video, simulations, and graphics. These features help offer an entry point for the text that is not solely based on reading comprehension. Additionally, online features are excellent tools for multilingual learners or students with specific reading disabilities (e.g., dyslexia).
- **Translator access:** Another advantage of online reading is the ability to use an electronic translator to help translate specific words or phrases. If you are able to copy and paste the text, you can usually use a translating service. Examples of text that cannot be copy and pasted might be those from pictures or low-quality PDFs.

Callouts for Representation, Action, and Expression

Throughout the materials, you will see a number of UDL, equity, or alternate callouts for strategies that help reduce barriers for students related to reading comprehension and writing. These are customized for each reading, though some will appear more than once. Some examples include:

Reading

- **Jigsaw** the reading (allow for choice in topics and/or guide students to "just right" level readings)
- **Chunk** the reading to vary the level of demand and complexity
- Allow for **choice -** students can read with a partner, with a teacher in a small group, or on their own

Writing

- Draw a picture that represents the ideas in the reading.
- Use a **graphic organizer** while reading to organize main ideas
- Ask students to **highlight their page** instead of writing to answer the prompts
- Provide **sentence stems and word banks** with each text. Or provide the text with **key words** highlighted to help with spelling challenges.
- Allow for a verbal exit ticket where students say their exit ticket answers instead of writing it
- Allow students to keep a digital science notebook if voice-to-text or typing are easier than handwriting.

In OpenSciEd Chemistry Unit 1 *Polar Ice,* teachers are provided with tips and options for structuring independent reading in Lesson 5:

3 · LEARN ABOUT TWO PROPOSED SOLUTIONS

20 min

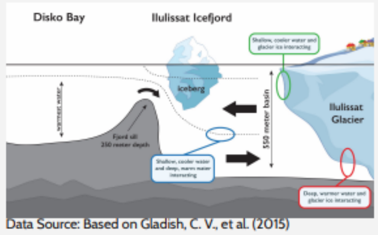
MATERIALS: science notebook, *Ilulissat Design Solution Proposals*, *Peoples' Concerns*, *Being Healthy* (optional), https://youtu.be/rdOst2woWww

Identify today's focal community agreement. Display **slide I.** Say, *We are going to learn about two possible solutions that engineers have proposed to reduce the amount of ice melt in this area. Before we do that, let's take a moment to consider how we can focus on being committed to our community while we learn about these proposed solutions. Turn and talk with a partner about how we can support this agreement today.* Call on a few students to share their ideas with the whole class.

Consider priorities for a design solution. Display **slide J.** Say, *When we read about these solutions, we will want to be critical evaluators of what the engineers have proposed. In your science notebook, take a few minutes to reflect on the different aspects we expect to see in a solution proposal and how much value you associate with them. Think about what you will prioritize when considering which solution is "better" than the other.* ✱

Introduce the two proposed design solutions. Say, *One way we can consider these design solutions is by attempting to understand how they would (or would not) work.* Display **slide K.** Distribute *Ilulissat Design Solution Proposals* to each student. Give students five minutes to do the following:

- Review the two proposed design solutions.
- Annotate the handout to indicate:
    - What makes sense about how the proposed solution would work?
    - What does not make sense?



Data Source: Based on Gladish, C. V., et al. (2015)

ADDITIONAL GUIDANCE

The diagram of the original design solution (published in Gladish, C. V., Holland, D. M., Rosing-Asvid, A., Behrens, J. W., & Boje, J. (2015). Oceanic boundary conditions for Jakobshavn Glacier. Part 1: Variability and renewal of Ilulissat Icefjord waters, 2001-14. *Journal of Physical Oceanography*, 45(1), 3-32. https://doi.org/10.1175/JPO-D-14-0044.1) was modified for increased accessibility for students. These modifications were:

- the use of "Ilulissat Glacier" rather than "Jakobshavn Glacier";
- the removal of extraneous labels/symbols (i.e., sill spillway and subglacial discharge);
- the removal of theta symbols and values and one intermediate water layer;
- the addition of captions indicating various water interfaces;
- the addition of an Inuit village on the glacier.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SYSTEMS AND SYSTEM MODELS

Over the course of the unit, students will consider two proposed design solutions. When they are introduced to these solutions during this lesson, students will need to consider how they are designed to do the specific task of preventing ice melt. In this instance, articulating the important parts of the Ilulissat Icefjord/Ilulissat Glacier system and how they interact, without the design solution in place, is useful when students think about how the design would change the system to accomplish the task.

✱ ATTENDING TO EQUITY

Support for Universal Design for Learning: To foster a safe, supportive reading culture in your classroom, consider structures for reading out loud. Some options include: allowing students time to practice reading the quotes ahead of time; asking for volunteers instead of cold-calling; encouraging students to choral read in groups of two or more. You can also distribute the quotes based on reading level. Group A readings (1, 4, 7, 8, 12) are the highest level; Group B (2, 6, 10, 13, 15) are the middle level; and Group C (3, 9, 11) are most accessible.

Approach to Reading Comprehension

Some readings are well-suited for more in-depth reading and text analysis. These may be found in lessons with a SEP 8 focus, or in other lessons. As students encounter these longer texts, the reading process can break down, especially for students who read below grade level. In these cases, you may see a callout referencing one of the strategies (more information can be found in the Appendix):

- Coherent Reading Protocol
- Think Alouds
- Reading for Gist
- the CATCH Method

A specific reading strategy like the Coherent Reading Protocol is based off sociocognitive reading comprehension work in schools asserting that students should be both "meta" and social with their reading (e.g., Brown & Palincsar, 1984; Zimmerman & Hutchins, 2003). Students should learn to monitor their reading comprehension as they go, and the community of learners should share strategies to repair their process. Following a specific reading comprehension strategy encourages readers to periodically monitor their thinking, return to the lesson question or anchoring phenomenon, and can help readers get "un-stuck". These strategies can be reduced in use over time. These strategies can be used for any text across the OpenSciEd HS program, as they are compatible with question-driven lessons.

These reading comprehension strategies work best for readers whose word decoding and sentence fluency are near grade-level, or in conjunction with screen readers or other assistive technology. For students who struggle with word-level reading, reach out to your school support personnel for additional guidance; they may already be receiving special education or English language support.

Developing Scientific Language

Conceptual Understanding First

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 OpenSciEd 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 to engage 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 on emergent multilingual students to engage in class discussions.

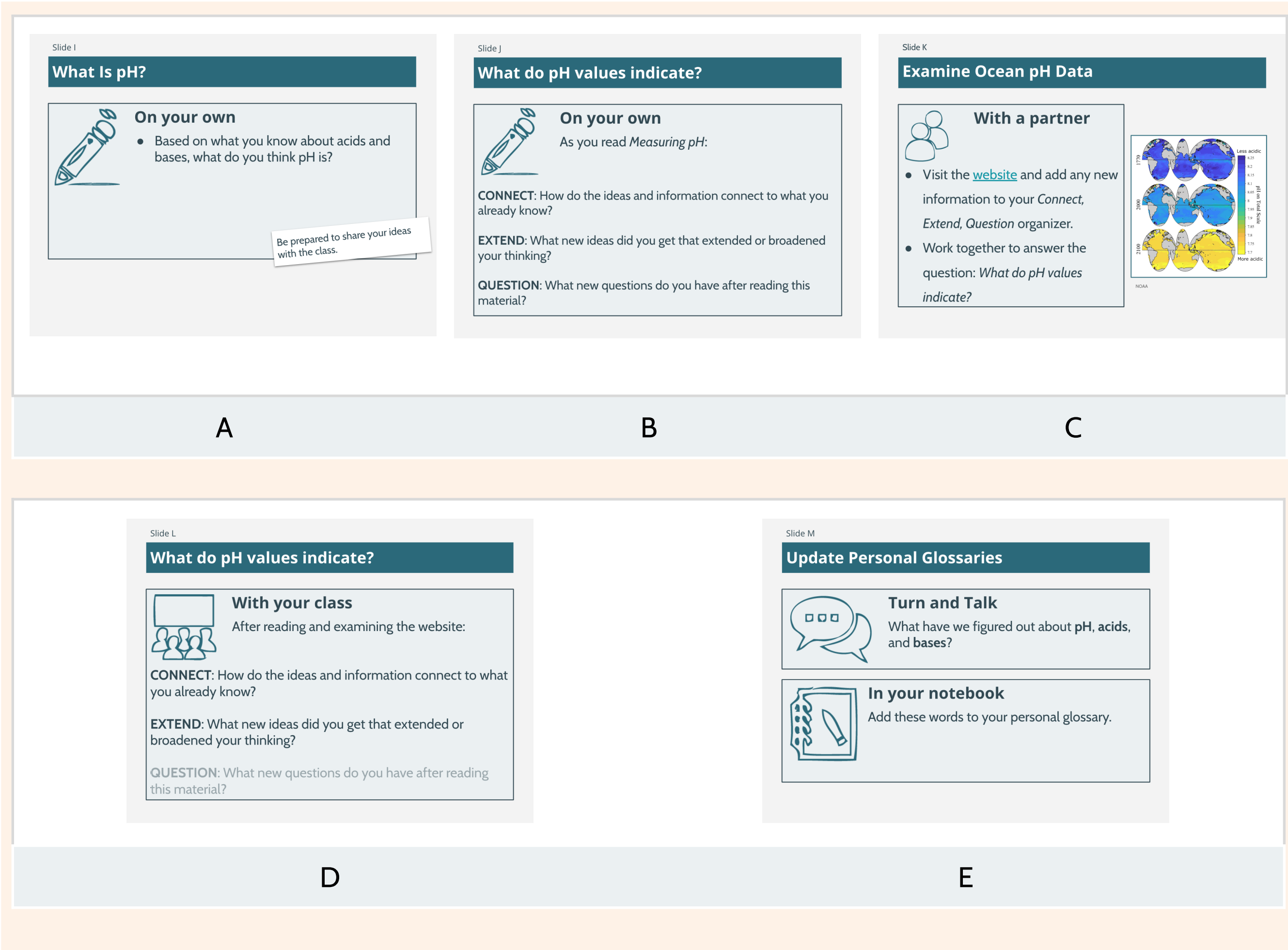
Students can communicate about and grapple with phenomena *without* using scientific terms. Once ALL students have developed a conceptual understanding of an idea in a lesson, introducing a relevant scientific term as a shorthand way to reference that idea makes complete sense. It is simply a matter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

This approach to vocabulary building doesn't undermine the sensemaking of students, nor 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.

Developing Personal Glossaries

After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have co-developed that definition and can add the specific term to a personal glossary at the back of their notebooks. These "definitions we co-develop" should be recorded using the students' own words whenever possible. On the other hand, "definitions we encounter" are "given" to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes definitions we encounter are helpful just in that lesson and need not be recorded in students' personal glossaries. However, if a word we encounter will be frequently referred to throughout the unit, it should be added.

In the following example from OpenSciEd Chemistry Unit 4 *Oysters*, students carry out an investigation to determine if atmospheric CO2 causes ocean water to become more acidic. After the investigation, they consider their informal understanding of pH, bases, and acids (A). They use the Connect-Extend-Question protocol to develop a working definition and understanding of pH (B, C, D). After this thinking and discussion time, they add the definitions to their personal glossaries (E).



It is best for students if you create consensus definitions in the moment, using phrases and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the meaning of the word, students “own” the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support. Sometimes defining a word is a challenge. The Teacher Guide provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate.

The definitions we co-construct and encounter in each unit are listed in the Teacher Background Knowledge and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

As new scientific terminology is developed with the class, we recommend that you build a word wall 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.

Writing in Science

OpenSciEd 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. 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.

Supporting Mathematics

The goal of integrating mathematics into OpenSciEd High School units is to use mathematical understandings and practices to make sense of science ideas. At the same time, using mathematics supports students in strengthening their mathematical understanding and practices, and demonstrates the importance of mathematical thinking and practices to science.

The OpenSciEd units are intentional in their placement and purpose of mathematics. Mathematics is intended to help to 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 to be used in isolation of developing understanding of the target science ideas. Connections to mathematics are noted at the end of each lesson where appropriate.

The OpenSciEd 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, the table below shows some examples of how the OpenSciEd High School Chemistry course builds mathematical thinking and concepts throughout the units.

Chemistry			
Unit Question	***C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities?***	***C.2: What causes lightning and why are some places safer than others when it strikes?***	***C4: Why are oysters dying, and how can we use chemistry to protect them?***
What lesson specific question(s) are we trying to answer?	Lesson 12: How can we slow the flow of energy on Earth to protect vulnerable coastal communities?	Lesson 5: What is happening at a particle level to produce static effects?	Lesson 8: How can we figure out how much of a substance we need to neutralize acid?
Why do students think analyzing data and/or using mathematical thinking might help our class answer this question?	There is a need to figure out if the berm solution would really prevent glacier melt as well as the class hopes it would.	Students investigated and recorded data about the relationship between force, charges, and distance with an algorithmic equation, Coulomb's Law for a small-scale system. Now, they want to see if the algorithmic relationships hold for a large-scale system.	Students use manipulatives to model a neutralization reaction and then carry out an investigation using the ratios of the balanced chemical equation to determine the masses of the acid and base involved. After carrying out the investigation, they figure out that the coefficients in a balanced chemical equation are not equivalent to mass ratios. Students are introduced to molar mass and use stoichiometry to determine

			how much of the base is needed to neutralize the acid.
How do students acquire the data?	*Calculating Berm Impact* handout and information from prior lessons.	*Solving for Force* handout.	Neutralization Investigations data
What tool(s) do students use to explore mathematical relationships?	Calculations using unit conversions	Calculations using Coulomb's Law and unit conversions.	Stoichiometric calculations using unit conversions
What types of relationships are students trying to identify?	Movement of energy into the Icefjord and effects on rates of glacial melt.	Effects of changing distance or charge on the force produced.	Ratios between masses of compounds to achieve specific results.
Do students develop and use equations from the relationship?	Yes	Yes	Yes
What other practices are students using mathematics in service of?	Students evaluate how well the berm solution works and create a model to predict impacts of human activity on Earth systems.	Students make predictions about the relationships between distance, force, and charge.	Students plan and carry out investigations to collect data so they can evaluate their mathematical predictions.
What do students figure out related to their question(s)?	The berm solution blocks enough calories of energy to stop the glacial melt.	Changes in distance impact the resulting forces between two charged objects more than the amount of charge on either object.	Molar mass must be used in conjunction with balanced chemical equations to determine how much of each substance to use in a chemical reaction.

Guidance on mathematical knowledge and practices can be found in the Teacher Background Knowledge for each unit to indicate alignment to the Common Core and to alert teachers for opportunities to attend to mathematics 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.

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices when conducting hands-on science investigations and demonstrations, whether in an instructional space (traditional laboratory or classroom) or in the field. To this end, teachers must be aware of any school or district safety policies, legal safety standards, and better professional safety practices that are applicable to the activities being undertaken.

Science safety practices in instructional spaces require engineering controls and personal protective equipment (e.g., sanitized safety goggles or safety glasses with side shields as appropriate, non-latex aprons and gloves, eyewash/shower station, fume hood, appropriate ventilation, and fire extinguishers). Science investigations should always be directly supervised by qualified adults, who should review safety procedures annually, and also before initiating any hands-on activities or demonstrations. Prior to each investigation, students should be reminded of the specific safety procedures they must follow. Each lesson within the OpenSciEd High School program includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as disassembling, disposing of, and storing materials.

Prior to the first investigation of the year, a safety acknowledgement form for students and parents/guardians should be provided and signed. You can access a model safety acknowledgement form for high school activities here: https://static.nsta.org/pdfs/SafetyAcknowledgmentForm-HighSchool.pdf

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

Please follow these lab safety recommendations for any science investigation:

- Wear sanitized safety goggles (specifically, indirectly vented chemical splash goggles) or safety glasses with side shields, as appropriate, a non-latex apron, and non-latex gloves during the set-up, hands-on investigation, and take-down segments of the activity.
- Safety goggles are required when working with liquid biological or chemical hazards (e.g., microbes, acids, bases, etc.).. Safety glasses with side shields or safety goggles may be used when working with physical hazards (sharps, springs, glass, projectiles, etc.)
- Immediately wipe up any spilled liquid (e.g., water) and/or granules on the floor, as this is a slip-and-fall hazard.
- Follow your Teacher Guide for instructions on disassembling and storing materials and disposing of waste materials.
- Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
- Wash your hands with soap and water immediately after completing the activity.
- Never eat any food items used in a lab activity.
- Never taste any substance or chemical in the lab.

- Use only GFCI protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
- Use caution when working with glassware, which can shatter if dropped and cut skin.
- Use caution when using sharp [tools|materials], which can cut or puncture skin.
- Never pour chemicals, either used or unused, back into their original container. Dispose of chemicals according to your teacher's instructions.
- If you get a hazardous chemical on your clothing or have a clothing fire, use the emergency shower.
- If you get a chemical in your eye, use an eyewash station immediately.
- Point the test tubes, beakers, or other vessels away from yourself and other people when the vessels contain reactants or other substances.
- When diluting acids or bases, the acid or base should be added to water and not water to the acid or base.
- Projective trajectory zones must be well defined and free of any obstacles. No participant is to be in the zone during operation of the projectile..
- Make sure the ventilation system meets the needs relative to removal of flammable vapors produced. Also make sure there are no active flames or sparks in the work zone.

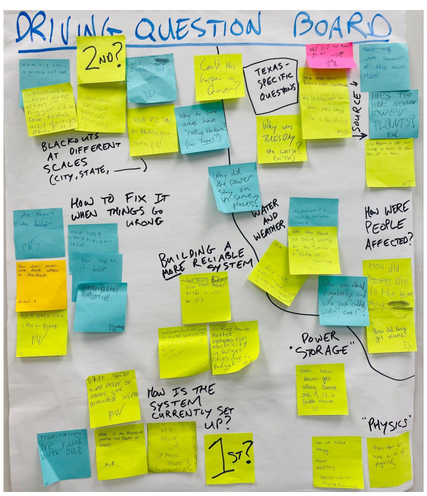
Specific safety precautions are called out within the lesson using this icon and a call-out box.

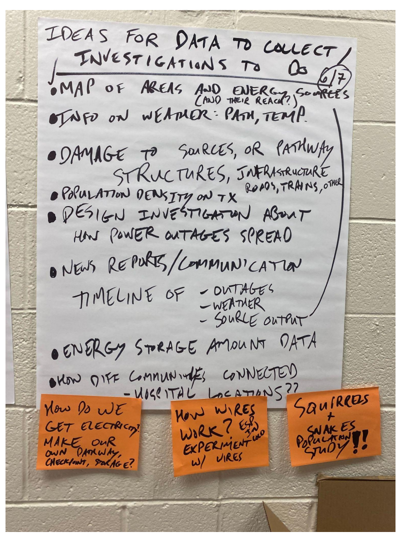
Appendix

Ideas for preparing a DQB for the start of each unit

- 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 post. 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:





Routines and Tools to Support Peer Assessment

Sticky Note Peer Review: In this protocol - from *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.

Peer Review with Rubrics: Some units include rubrics to support peer assessment. For example, You can also use these as a way for students to assess each other's work and give feedback on how to revise it specific to the rubric criteria.

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.

Support for specific and actionable peer feedback

Support students with examples for productive and nonproductive feedback as they learn to give productive feedback. Examples are included below.

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 are:

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

Sentence starters for actionable 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, ask 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.
- 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 specific and about science ideas.		
Shared a suggestion to help improve my peer's work.		
Used evidence from 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
Read the feedback I received carefully		
Asked follow up questions to better understand the feedback I received		
Said or wrote why I agreed or disagreed with the feedback		
Revised my work based on the feedback		

What is one piece of feedback you received?

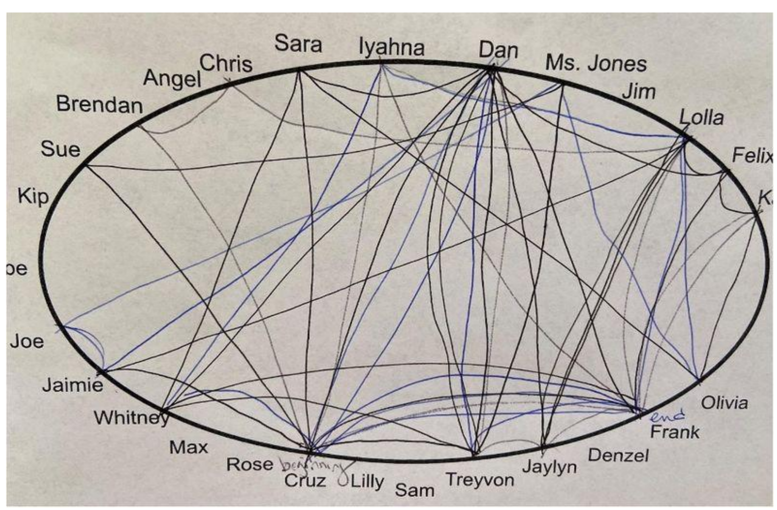
What did you add or change to address this feedback?

Discussion Mapping Tool

Instructions

1. Print one copy of the second page of this tool for each class section.
2. Add students' names to the circle in the order that students are sitting. You may want to do this ahead of time, and then ask students to sit according to the map.
3. Write the question that students are trying to answer at the top of the page.
4. Select a student recorder who will map the discussion as it happens. Decide ahead of time whether you will have multiple students take turns mapping, and when you will move the map to a new student recorder.
5. If this is the first time you are using a discussion map, explain to students that each time someone speaks, the recorder will draw a line from the previous speaker to the new speaker's name. You may want to mark where the conversation begins and ends, but the goal is to map the overall conversation patterns rather than to be able to retrace the entire conversation.
6. Once the discussion begins, allow students to take the lead in moving the discussion forward. Sit in the circle as a participant rather than standing in front of the class as a facilitator. This will allow students to practice building on each other's ideas directly.
7. Be mindful of group dynamics, especially when displaying the map and discussing patterns of contributions. Avoid focusing on the contributions of single students, and instead redirect the class to notice class-level patterns.

An example of a completed discussion map is pictured below:



Discussion Mapping Codes

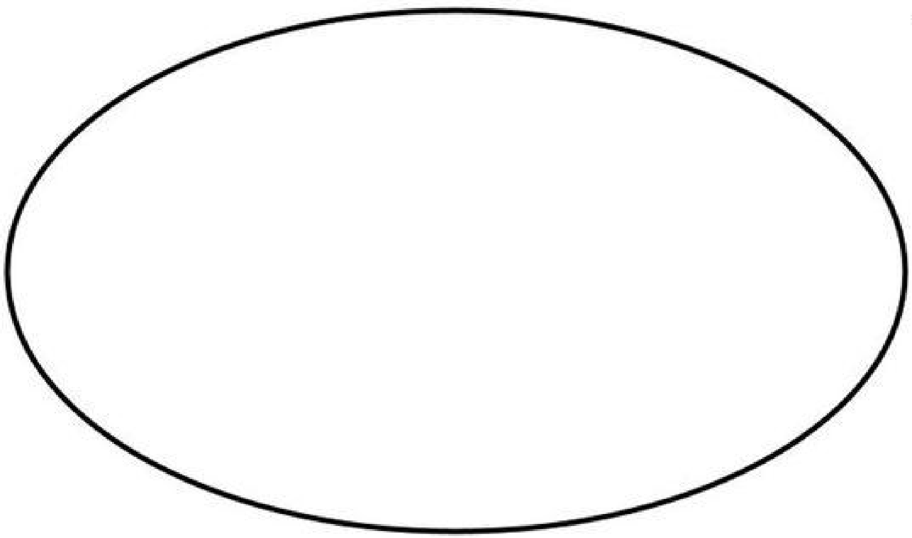
The key at the bottom of the discussion map contains codes that can be used to label the types of student contributions. The first few times you create a discussion map with your students, you should focus only on recording the flow of the conversation. This allows students to get comfortable with the process. Once students have experience recording and interpreting those initial patterns, you can add discussion mapping codes to future discussion maps. There is an extra column where you can add your own discussion codes as needed, based on individual class needs and agreements. You may also choose to only use some of the discussion codes, based on the type of discussion your students are having. In this case, be sure to cross out the codes you are not using so the student recorders know not to include them.

Key Ideas

There is space to list up to three key ideas that emerge from the discussion on the tool itself, so the class can keep track of the ideas raised in the discussion. If you choose to use codes to annotate student contributions, you can also use the codes “1”, “2”, and “3” to map when those ideas are talked about.

Question we are trying to answer:

Directions: Write your students names around the circle, according to where they are sitting in the room. **Tip:** Find a landmark for you and add it to your image!



Key Idea 1:

Key Idea 2:

Key Idea 3:

Discussion Mapping Codes					
C- claim given	**CL**- clarified idea	**?**- asked question	**T**- tied ideas together	**I**- interrupted	1- Key Idea 1
E- gave evidence	**A**- affirmed/agreed	**NI**- new idea added	**RP**- related phenomena		2- Key Idea 2
OT- off topic	**D**- disagreed	**R**- repeated idea	•- idea ended		3- Key Idea 3

Discussion Planning and Reflection Tool

Discussion Planning and Reflection Tool

A. **Before the discussion (Analyzing and reflecting on the lesson in the Teacher Guide):**

1. What is the question students are trying to answer through this discussion?

2. What is the intended outcome of the discussion? (Coming to consensus on something we just experienced? Figuring out improvements to our 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? (Create an explanatory model for this phenomenon for yourself.)

4. What other ideas might students have? What questions might they ask?

B. Leading the Discussion (Considering talk moves and strategies in Teacher Guide)

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 synthesize what it is you all agree on and/or what new questions you have?

C. Reflection: After the discussion (Spend 10-20 quiet minutes writing.)

1. What ideas and reasoning did you hear? How would you describe the group's understanding of the ideas you identified in question 3 of your planning?

2. What went well in the discussion?

3. What was challenging?

4. Describe a moment when you weren't sure what to do. What *did* you do and why? And what was the result?

5. Anything you would do differently if you could do it over?

OpenSciEd High School Coherent Reading Protocol

(This is a student-facing protocol to copy/paste into lesson materials)

These prompts are designed to help you make sense of the main ideas from any reading.
Identify at least 3 chunks of text before you start. Stop and write the main idea after each chunk. Use the back of this page if you have more than 3 chunks.

Navigate into the reading: What will you figure out as you read?

Text Chunk 1: Write the main ideas in your own words. (If you aren't sure, reread and annotate.)

Text Chunk 2: Write the main ideas in your own words. (If you aren't sure, reread and annotate.)

Text Chunk 3: Write the main ideas in your own words. (If you aren't sure, reread and annotate.)

Choose one of these questions to write about as you navigate back to your lesson question.

- ☐ Evaluate the usefulness of this reading. What did the reading help you figure out our lesson question?
- ☐ What questions did the reading raise for you?
- ☐ What does this reading make you wonder?

Star ✱ 1-2 ideas you wrote that you are confident sharing with your peers.

CATCH Method for Annotations

CATCH is an acronym that represents the process of actively reading and engaging with a text. CATCH can be used to effectively annotate any kind of text (fiction, non-fiction, graphic, visual), which makes it a great tool for students to use throughout their classes, and it makes it a great tool for building an academic culture and literacy school-wide.

While there is no "proper" order or method for annotation, capturing the main idea generally comes at the end, after you have read the text one or more times, cleared up any confusion or answered any questions you had, and engaged in a dialogue with the text. Any other symbols--, !!!, ?, *, ...--are left to the individual.

C	**Circle** unfamiliar words (then define them)	*Is knowledge of a particular word's meaning essential to understanding the text?*
A	**Acknowledge** confusion (and wrestle with it)	*At what parts of the text am I getting confused?* *Why am I confused?* *What do I think this part of the text means?*
T	**Talk** with the text · comments · questions · predictions · observations · connections · reactions · identify author's evidence · rhetorical devices	*Talking with text should go hand-in-hand with highlighting. If a detail is important enough to highlight, I need to express my thinking about it.*
C	**Capture** the main idea	*Is the main idea explicitly stated? If so, where?* *Is it implied? If so, how could I explain it in my own words?*
H	**Highlight** or underline important details	*Less is more.* *Avoid highlighting complete sentences.* *Too much highlighting makes nothing stand out.*

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Additional Literacy Resources

The Reading for Gist protocol helps students summarize hard-to-access information by breaking it down into the main parts of *Who? What? When? Where? Why? And How?*. The following websites contain helpful resources about the Reading for Gist protocol:

- American University: https://www.american.edu/provost/academic-access/upload/gist-strategy.pdf
- IRIS Center Peabody College Vanderbilt University: https://iris.peabody.vanderbilt.edu/module/csr/cresource/q2/p07/

When teachers use the **Think Aloud teaching strategy** for reading comprehension, they read a paragraph or text selection aloud and pause to share their "meta" thinking as a reader to the class. They might say something like "I bet this paragraph will be about __" or "Oh, I've heard of that!" or "Wait, I'm a little confused here. What is the author saying?". This research-based practice models and helps students build the social practice of reading and thinking. For more information, visit https://www.facinghistory.org/resource-library/think-aloud.

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