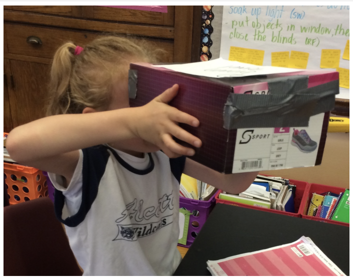
Teacher Handbook for NextGen Science Storylines

Teacher Handbook
v1.1 Oct 2019



NextGen Science Storylines are instructional units developed by the NextGen Science Storylines Project at Northwestern University (nextgenstorylines.org). These units reflect the storyline approach from Reiser, Novak, and McGill (2017), in which the questions and problems students identify drive the sensemaking of the unit.

In a storyline, students should see each new lesson as helping them address questions or problems their classroom has taken on. The units use anchoring phenomena to begin the investigation and storyline teaching routines that help teachers navigate so that students' questions continue to drive the sensemaking.

These units are designed to reflect the recommendations of the Framework for K-12 Science and the Next Generation Science Standards (NGSS). The NextGen Science Storyline units are open-educational resources and may be freely downloaded and adapted for local contexts.

This Handbook is designed as a resource for teachers to use as they plan to teach with NextGen Science Storylines. Each NextGen Science Storylines unit provides specific teacher guides and student materials for use in the classroom. This Teacher Handbook presents an overview of the instructional approach used in NextGen Science Storylines units.

Each chapter of this handbook outlines the key instructional shifts in the storyline approach to three-dimensional learning. The Handbook is intended to be used in conjunction with the collection of resources that provide unit-specific guidance for each of the NextGen Science Storyline Units. Important unit-specific resources for implementing a particular storyline include the unit-specific front matter, the unit storyline, assessment guidance, and the teacher guides for the individual lessons.

These materials were developed with support from the Gordon and Betty Moore Foundation, the James S. McDonnell Foundation, and the Carnegie Corporation of NY to Northwestern University.

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A. What is a NextGen Science Storyline?

A NextGen Science Storyline[1] is an instructional unit that is a coherent sequence of lessons, in which each step is driven by students' questions that arise from their interactions with phenomena. The students' goal across a storyline should always be to explain a phenomenon or solve a problem. At each step, students should make progress on the classroom's questions through science and engineering practices, using and building science ideas and furthering their sophistication with the practices, always working toward explaining phenomena and solving design problems.

Each step may also generate new questions that lead to the next step in the storyline. The class puts together what they figure out in each lesson to help explain the unit's phenomena or solve the problems they have identified. A storyline provides a coherent path toward building disciplinary core ideas and crosscutting concepts, piece by piece, anchored in the students' own experiences and questions, using and further developing their science and engineering practices.

In many previous science units, instructional materials are organized based on how experts understand the relationships between the science ideas. One may see a sequence of chapters or lesson plans organized by the logic of the discipline. This logic may be clear to teachers or curriculum writers, but may not make sense to students at all. For example, a teacher may understand how certain activities to learn about cells will help students understand important biological concepts of how systems work in living things, but students may only know that they are learning about cells because that's the title of the current chapter in the textbook. Or a teacher may know how a particular chemistry experiment demonstrates something about conservation of matter, but the only reason her students may have for doing that experiment is that it is part of their assignment from the teacher.

In the storyline approach used in the design of our units, the sequence of activities is designed to enable teachers to work with students' ideas so that the goals of the unit and how it unfolds over time make sense to students (Reiser, 2013; Reiser, Novak, & McGill, 2017). We call this "coherence from the students' perspective." When a storyline is coherent from the students' perspective, a visitor to the classroom on any given day should be able to walk over to a group of students and ask them why they are doing what they are doing. Students should be able to answer by describing a question they are trying to figure out or a problem they are trying to solve, and not just say, "Because my teacher told me to do this." They should also be able to explain how they helped the classroom community decide what they should do to investigate that question or design a solution to the problem.

Figuring out is not a process a classroom community can do by jumping from topic to topic or from lab to lab. Practices are more than just technical skills, like learning to use a microscope or balancing equations. Practices refer to how a community works together, guided by common goals, norms, and language to make progress. Science and engineering practices guide the work with phenomena and problems so students can develop, test, and refine science ideas. Engaging in practices means students should know *why* they are doing what they are doing, and should *buy into* these goals.

In this way, each storyline is a path in which all of the students help manage the trajectory of their knowledge building. The class as a whole, which includes students and the teacher, develop ideas together over time, motivated by questions about phenomena in the world, where each step is an attempt to address

[1] Portions of this description of the storylines approach were included in the front matter of the 2018 NextGen Science Storyline, *How Can We Sense So Many Different Sounds From A Distance?* [v2.1], and were adapted for later use in the OpenSciEd *Teacher Handbook* (2019).

a question or gap in the classroom's current explanatory model. **The storyline approach supports students' agency in sensemaking:**

- **WE** figure out the science ideas.
- **WE** figure out where we are going at each step.
- **WE** figure out how to put the ideas together over time.

Thus, a storyline reflects a path to support sensemaking that is coherent from the students' perspective. At the same time, a storyline does *not* mean that teachers need to follow students wherever their questions and ideas take them. Storylines are designed to meet target NGSS performance expectations, and the sequence of phenomena, problems, and questions are carefully planned in advance and laid out in the storyline and teacher materials. A storyline is more than a cleverly designed sequence of phenomena. It requires teaching strategies to bring students in as partners in developing and managing investigations that will be productive for the learning goals. Storylines are extensively tested and revised to ensure that teachers can work with the sequence of phenomena and problems to involve students as partners (not as the sole drivers) in developing questions or identifying problems that lead to the targeted investigations. Teachers need to work to elicit and provoke students' questions, guide and challenge their developing models, and bring in helpful investigative and conceptual tools to help students make progress.

B. How Are NextGen Science Storyline Units Organized?

NextGen Science Storyline units[2] are organized into collections of lessons called *lesson sets* (which were called *bends* in earlier NextGen Science Storyline releases). In each lesson set, the classroom advances the storyline by investigating one aspect of the anchoring phenomenon or problem. In each lesson set, students pose questions about some aspect of a phenomenon, explore the phenomenon through scientific investigations, and work to make sense of their investigations. At the end of a lesson set, students put their ideas together to refine their explanatory models or design solutions,

A lesson set is made up of individual lessons, each of which has several parts, or *activities*, that work together to help students make sense of some phenomenon or problem. Lessons may range in length from one class period to several. Here is the general structure that our units each follow:

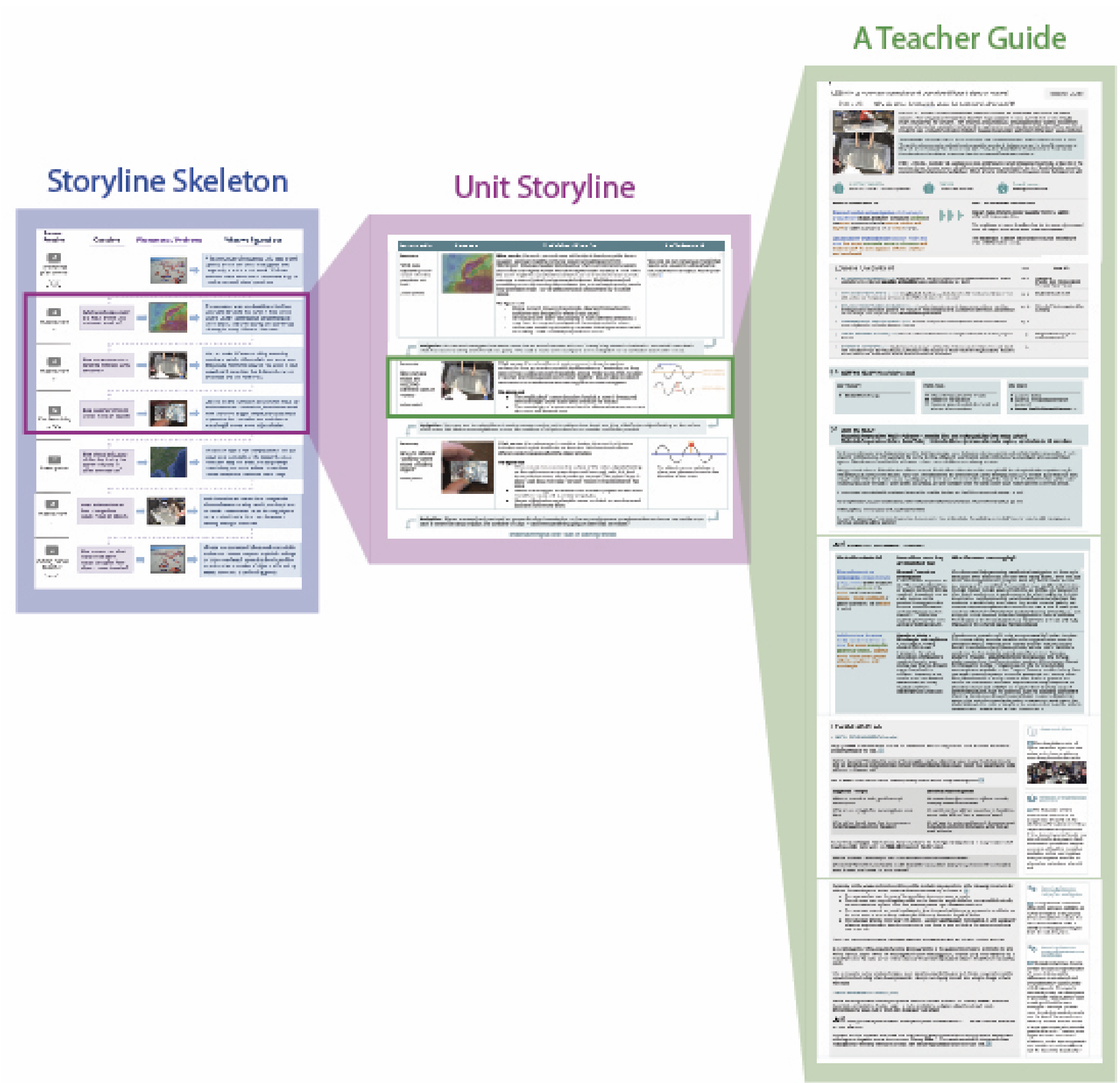
Unit: Unit Driving Question (i.e., the unit title)
- Lesson Set 1
  - Lesson 1: Anchoring Phenomenon and Driving Question Board
    - Activity 1: Name of Activity...
    - Activity 2: Name of Activity...
  - Lesson 2: Investigation
  - Lesson 3: Investigation
  - Lesson 4: Putting Pieces Together and Problematizing
- Lesson Set 2: Lesson Driving Question
  - Lesson 5...

[2] Portions of this section were adapted from the OpenSciEd Teacher Handbook (OpenSciEd, 2019). OpenSciEd units were developed with the collaboration of the NextGen Science Storylines team, and are structured using the storyline model developed earlier in our earlier storylines work.

The next section presents a description of the instructional model that underlies the design of the trajectory of these lesson sets.

C. What Resources Are Included to Help Teach with a NextGen Science Storyline?

Each unit has three principal interconnected planning resources - the *storyline skeleton*, *unit storyline*, and *teacher guides* (summarized in the figure below). Each of these materials provides progressively finer detail about what is in a particular lesson. The storyline skeleton shows the overall trajectory of students' sensemaking across the unit. The unit storyline summarizes the sensemaking work in each lesson, from the questions and problems that drive the work to what the students figure out. The teacher guides provide a detailed learning plan to help teachers facilitate the learning activities for each lesson.



NextGen Science Storylines are shared as collections of digital resources. They are implemented as a set of Google Drive files (slides, docs, sheets), with accompanying videos, images, and other instructional materials. These can be accessed by the teacher via any web browser. Each resource is licensed under a Creative Commons Attribution-NonCommercial 3.0 License https://creativecommons.org/licenses/by-nc/3.0.

Within Google Drive, the reference versions of the curricular materials cannot be edited; teachers must first copy the folders to their local system before sharing or making changes. Certain materials, such as student handouts, are designed to be easily printed.

Here is the general folder structure and descriptions of the resources these folders contain.

Folder	Types of Documents	Description
A. Unit Front Matter	Unit Front Matter	A single document with the following sections: ● Synopsis: A one-page overview of the driving question or problem, major investigations, and what students figure out ● Performance expectations targeted in the unit ● Unit calendar ● Guidance for particular unit-specific instructional strategies used in the unit ● Guide to assessment resources for the unit, including formative assessment opportunities and potential responses in each lesson, and unit assessments ● Development team and history
B. Storyline Documents	Storyline Skeleton	The trajectory of lessons laid out as the question that students will investigate in each lesson, and image of phenomena they investigate, and a summary of what students figure out.
	Unit Storyline	A more detailed version of the Storyline Skeleton, with details about the full set of phenomena that students will investigate in each lesson, and an itemized breakdown of what students figure out and what questions they generate. Each lesson is summarized in its own table.
C. Lesson Resources (This folder contains several Lesson Set folders. Each lesson set folder contains a folder for each lesson in the set.)	Teacher Guides	Teacher Guides 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 that teachers can use in planning instruction for their specific settings and students.
	Presentation slides	An editable set of slides that teachers may project as they move through the lesson, for teachers who prefer to use slides (included only in units for Grades 4-12).
	Additional teacher resources	Lab instructions, answer keys and rubrics, included where relevant.
	Student resources	Readings, references, and lesson procedures for students to use

	Student handouts	Designed for situations where students need to draw or write on an image or graphic organizer (to be copied for each student).
	Interactive student resources	If a lesson contains interactive simulation, resources will be available in the Lesson folder.
D. Unit Assessments	Assessment Opportunities for the unit, plus additional documents	A set of summative assessments, rubrics, scoring guides, and unit-wide assessment opportunities. It also contains an pre-post assessments and student self assessments or general exit tickets to be used across more than one lesson.
E. Classroom Materials	Materials List	A list of materials and supplies that the school will need to purchase to support student investigations for the unit, including quantities and suggested sources.

D. What Are the Assessment Resources in a NextGen Science Storyline?

We[3] have developed a system of assessments that is grounded in sociocultural theory of learning (Penuel & Shepard, 2016) and that adheres to the recommendations of the National Research Council (2014) report, *Developing Assessments for the Next Generation Science Standards*. This report recommended the use of multi-component tasks as a centerpiece for assessment, that is, tasks that are organized around a scenario presented to students that tests their ability to apply understandings of core ideas and crosscutting concepts to explain a phenomenon or solve a problem using science and engineering practices.

Each unit includes an Assessment Opportunities document that offers an overview of the different types of assessments throughout the lessons, including pre-assessment, student self-assessment, summative assessment, and formative assessment. These summative and formative assessment opportunities are also highlighted in the individual teacher guides for each lesson.

Types of Assessments

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

- **Pre-assessment:** Pre-assessment opportunities are found in early lessons in the units, usually in the form of initial questions, models, explanations and ideas for investigations. The goals of pre-assessments are: (1) to give teachers evidence for what ideas and practice competencies students are bringing into the unit and (2) to get a diverse set of ideas on the table that teachers can leverage throughout the unit to support argumentation and sensemaking. Many embedded instructional activities can be used as pre-assessments including initial models, driving questions for the DQB, and discussions around early class consensus models.

[3] The assessment approach described here was developed through collaborations of the Inquiry Hub (Severance et al, 2016), NextGen Science Storylines, and OpenSciEd projects. Portions of this section have been presented in the front matter of the Inquiry Hub / NextGen Science Storylines unit *Why Don't Antibiotics Work Like They Used To?* [v3.1], the front matter of the 2018 NextGen Science Storyline, *How Can We Sense So Many Different Sounds From A Distance?* [v2.1], and the OpenSciEd *Teacher Handbook* (2019).

- **Self assessment:** Self assessments are opportunities for students to learn and grow from their participation in the class learning community. Teachers can decide wherever in the unit they would like to help students reflect on their growth. In addition, specific opportunities are identified in the unit where teachers can have their students self-assess their progress using more generic self-assessment tools. For example, the discussion rubric helps students understand and apply criteria for large- and small- group classroom communication.
- **Summative assessment:** Summative assessment opportunities are built into the unit and can occur at the end of each lesson set or the end of the unit. The purposes of summative assessment are to obtain evidence of what students have learned to (1) provide them with information on where they are in their learning (compared to where they need to be), and (2) provide teachers with information to adjust future instruction and usually assign a grade. Summative assessments can be transfer tasks where students are asked to make sense of a new phenomenon or they can be final models, arguments or explanations of the phenomenon explored in the unit. Either way, summative assessments should be closely linked to the targeted performance expectations and directly address concepts and practices that the unit focuses on developing and using.
- **Formative assessment:** Formative assessments are meant to guide and advance learning by providing information that helps teachers learn about their students' strengths and weaknesses and make subsequent instructional decisions. Formative assessment opportunities are built into the unit and meant to be points along the way where teachers can see where students are as they build understanding. In three-dimensional science instruction, this often means formative assessment happens as students are still working on building their understanding across the units and will often assess incomplete pieces of the final understanding. Look for formative assessment opportunities for each lesson's performance expectations in the "Lesson-by-Lesson Assessment" table. This structure of this table is described in the next section.

Formative Assessments and Lesson-Level Performance Expectations (LLPEs)

A lesson-level performance expectation (LLPE) is a three-dimensional learning statement for each lesson aimed at highlighting the key student expectations for that lesson. Every NextGen Storylines lesson includes one or more LLPEs. The structure of every LLPE is designed to incorporate three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The color font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

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

Through this set of assessments, each unit provides opportunities for assessing students' individual or independent mastery of the performance expectations as well as for assessing the group's progress in explaining anchoring phenomena or solving design challenges. In addition, exit tickets and self assessments provide the student and teacher with measures of student perception of belonging, agency, and growth over time.

Early releases of NextGen Science Storylines may include a smaller subset of these resources developed for the unit. For example, transfer tasks may not be included in the first release of the unit, but will be included in future releases once they are developed. Detailed guidance regarding which of the above assessments are included in the version of the unit that is released will be summarized in the Assessment Opportunities document in the "Unit Assessments" folder.

E. What Instructional Strategies Are Used in NextGen Science Storylines?

The NextGen Science Storylines units use a common set of instructional routines -- ways of structuring activities to accomplish particular aspects of the storyline approach. For example, all storyline units begin with an anchoring phenomenon or problem. While the specific kinds of activities and tools may vary from unit to unit, each anchor includes an opportunity for students to explore the phenomenon or problem, attempt to make sense of it, and develop questions. These questions may be recorded using different types of tools (a driving question board, notice and wonder charts, or other approaches), but what is common is that interacting with the anchor is intended to raise questions for students as they attempt to make sense, and these questions are shared and recorded.

Reiser, Novak, and McGill (2017) presented an initial analysis of five instructional routines that reflect the storyline approach. In this section, we describe these five routines and how they are typically implemented in NextGen Science Storylines units[4].

Routine	Pedagogical Purpose
Anchoring Phenomenon Routine	The class engages with a common phenomenon through which the class develops questions or identifies problems, which then establish the need for the learning the class will do in the unit.
Navigation Routine	Teachers and students together consider what the class has figured out so far and what limitations or problems have been uncovered, what questions or problems are still pending, and determine the next steps that will further the sensemaking.
Investigation Routine	The class uses science and engineering practices to investigate and make sense of a phenomenon or solve a problem, extending what the class has figured out.
Problematizing Routine	The class evaluates the adequacy of scientific evidence, models, or solutions to identify limitations in their explanations or designs, which set further directions for the work.
Putting Pieces Together Routine	The class assembles and synthesizes pieces of ideas developed across multiple lessons to explain target phenomena or solve identified problems.

[4] The storyline routines were initially presented by Reiser et al. (2017). Earlier versions of the descriptions of these routines were included in the front matter of the 2018 NextGen Science Storyline, *How Can We Sense So Many Different Sounds From A Distance?* [v2.1], and then were adapted and extended in the OpenSciEd *Teacher Handbook* (2019).

How and where the routines are found will vary somewhat across different NextGen Science Storyline units, but these routines typically follow a pattern as students kick off a unit of study, investigate different questions they have, put the pieces together from those investigations, and then problematize the next set of questions to investigate. Each unit will have a slight variation on what happens within a particular routine, based on the anchoring phenomenon and the focal SEPs and CCCs, but the purpose and general approach of the routine is consistent across all units.

The next sections describe the five routines, their purpose, the elements that comprise them, and provide examples of how they can be supported with classroom discourse.

Anchoring Phenomenon Routine: Kicking off a Unit with an Experience to Motivate Further Investigation

What is it, and what is its purpose?

The Anchoring Phenomenon routine is used to kick off a unit of study and drive student motivation throughout the unit. The purpose of the Anchoring Phenomenon routine is to build a shared mission for a learning community to motivate students in figuring out phenomena or solving design problems. 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.

The Anchoring Phenomenon routine:

- creates an opportunity for students to voice their initial ideas about the phenomenon;
- identifies the areas of agreement and disagreement in students' ideas about the mechanisms behind one or more aspects of the phenomenon;
- Helps the teacher identify the prior knowledge and experiences students bring to these questions;
- invites students to connect what they are doing to their own experiences in their own world;
- elicits questions that the students want to investigate and answer throughout the unit, which the teacher will be able to use to motivate students and connect the lessons in the unit.

When is it done within a unit?

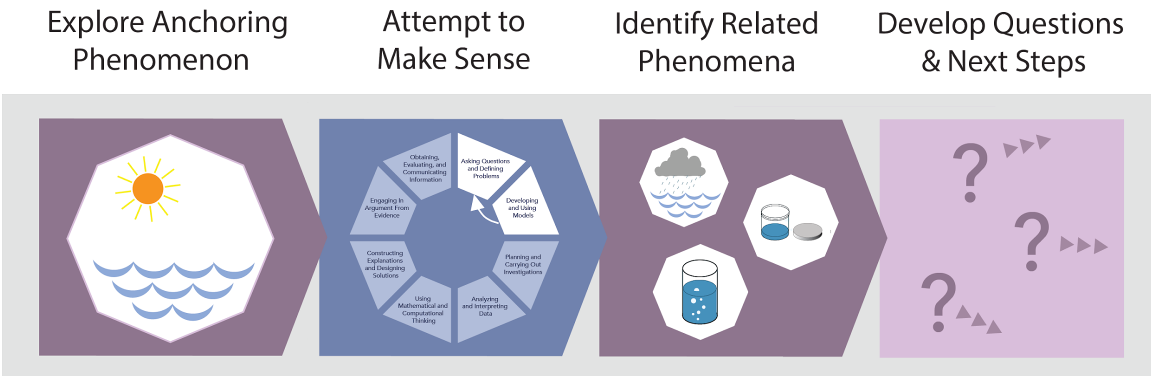
The Anchoring Phenomenon is introduced at the beginning of a unit.

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

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

Elements of the Anchoring Phenomenon Routine

There are four elements that make up the Anchoring Phenomenon (AP) Routine. This is not meant as a strict sequence. The order of these elements may be different in different units, and students may revisit these elements more than once during the Anchoring Phenomenon Routine. Each of these four elements play a key role in helping classrooms craft a shared set of questions and ideas for future investigations that will be aligned to the instructional arc of the storyline.



Element 1: Explore the Anchoring Phenomenon:

Every instructional unit should start with some puzzling phenomenon that students experience. In this section, students explore that phenomenon in some way. The question the class is working on is; “What do we notice?” For example, students might make observations, look for patterns, or create a timeline of events that occurred. The purpose of this section is for students to recognize the interesting events going on and to publicly, as a learning community, acknowledge aspects of the phenomenon that require key pieces of target DCIs to explain.

Element 2: Attempt to Make Sense

Students should try to come up with an explanation, model or some other reasoning to explain why or how the phenomenon under investigation is happening. One might wonder about the benefits of this initial attempt to make sense of the phenomenon. For example, one might argue that we expect students don’t yet understand what’s going on in the ancor. So why take the time for students to try to explain the phenomenon if it is likely to be wrong, and set up a context in which students would experience “failure” to answer their questions? It is important to stress, in contrast, that the intention of this element is not to have students come up with the “right” answer. The purpose is to start to stake out the territory of what the classroom community recognizes now that they don’t completely understand, so they can work on a plan to figure out those questions. Sometimes students don’t see what is important or problematic to explain until they are pushed to go beyond simple statements of cause (e.g., “the sound went through the wall”). Trying to explain an apparently unremarkable phenomenon can help students identify questions they cannot answer scientifically -- e.g., “What is it that is going through the wall?” “How can sound go through solid objects?” “Why are some walls better at stopping sound than others?””

For these reasons, it is important that each student tries individually to attempt to make sense of the phenomenon and then go public with his or her ideas. Diversity in our sense-making ideas is productive for the classroom community! It can help create the sense that “we are not all on the same page,” and that therefore there are questions that need to be figured out.

The role of the teacher at this stage is two-fold: (1) to help students get their thinking down on the page, regardless of how scientifically accurate it may be, and (2) to push students to come up with a mechanistic explanation about what is going on. Press students to go deeper if they think they know the answer. Teachers need to help students see that the goal is not to know the special science label (e.g., “amplitude,” “frequency,” “molecule”). Rather the goal is to explain step by step how and why the phenomenon happened. Students who know the scientific label may not be able to explain the cause and effect chain that leads to the phenomenon. And students may be able to say more in everyday language than what they can label with precise scientific vocabulary.

Attempting to make sense of the anchoring phenomenon might include several steps, such as:

- individual sensemaking first (e.g., developing an individual model)
- comparing ideas with peers (e.g., considering how their own model compares to another's—it can be done with a partner, small group, or gallery walk)
- class sensemaking conversation and initial consensus model

Element 3: Identify Related Phenomena

The goal of NGSS storylines isn't just to solve a single mystery about one phenomenon; the goal is to develop disciplinary core ideas and crosscutting concepts that can be applied to a range of events in our world. The purpose of having students generate related phenomena is to broaden out the scope of what the class is interested in figuring out. It can also enable students to bring in their own experiences that make the questions connected to the science ideas more relevant and personal for them. In fact, if students are not able to come up with related phenomena, that might be a sign the anchoring phenomenon needs to be adjusted because students will not care or relate to what the class is working on.

Identifying related phenomena might include several steps, such as:

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

Element 4: Develop Questions and Next Steps

In this part of the activity, the class makes a joint list of questions and action items to accomplish their mission of figuring out the driving question of the unit. What's unique about three-dimensional learning is the opportunity for students to be involved in the thought process and decision-making about *what* the class should be figuring out and *how* the class should be figuring it out. It is important for each student to participate in generating a question to be explored and for those questions to be made public so that the class as a whole retains ownership of those questions. This process may take on various forms, such as a "Driving Question Board" or a "Notice and Wonder chart" or other summary representation. Along with generating questions, students should be involved in thinking about ways to go about answering one or more of the questions from the class. This early in the unit, it is not important that the ideas for investigations have a step-by-step procedure; they don't have to be what is considered an "experiment." Rather, the point is that students are identifying actionable ways to figure out answers to their questions. For example, maybe the class thinks a good way to follow up on one of their questions is to look up what experts have to say or gather secondhand data. Also, the goal isn't to come up with the perfect question or solution, as long as the student can articulate the rationale for how the investigation would help the classroom community make progress on the questions they have identified.

The questions and next steps should be kept as a public class record and should be kept alive. Questions and next steps should be revised, revisited, and checked off as the unit progresses. This process might include several steps, such as:

- The teacher asks, "What do we want to know next?"
    - Students write individual questions.

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

For additional support, teachers may wish to consult the Storyline Planning Tools on the NextGen Science Storyline site. Storyline Tool #1 provides a planning template for supporting the implementation of the Anchoring Phenomenon Routine.

Navigation Routine: Determining Next Steps in an Investigation

What is it, and what is its purpose?

The Navigation routine enables students to experience the unit as a coherent storyline in which each activity has a purpose that is connected to what has gone before and what is coming. It also provides a valuable opportunity for students to reflect on their learning over time. It is critical in maintaining the classroom work as meaningful to students, where they can explain how each step the class takes will help them make progress on the questions or problems they have identified, rather than simply "following instructions" from teachers and textbooks about what to do next.

When is it conducted?

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

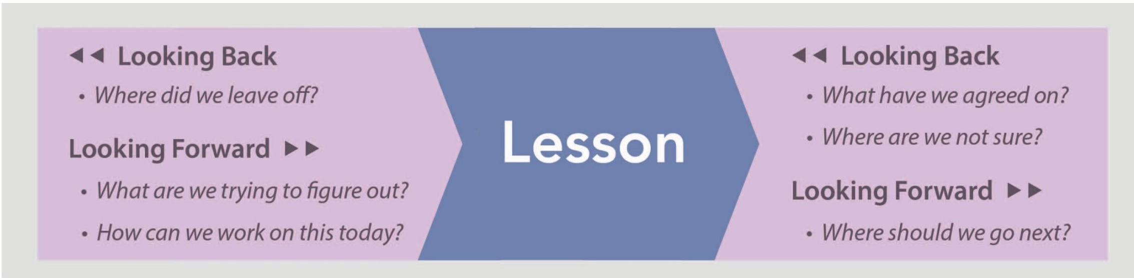
How do students typically represent their thinking as part of the routine?

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

- Discussing how to articulate what the class has figured out, and recording it on a progress tracker
- Recalling what the class figured out last time
- Articulating new questions that seem logical to pursue next
- Revisiting their initial ideas and focus questions in their science notebooks
- Returning to the Driving Question Board to answer questions, add new questions, or refine their questions
- Considering how an idea for an investigation might help the class make progress

Typical Elements of the Navigation Routine

There are two main parts of the Navigation Routine, which occur between every lesson in the unit. Consider what is involved in navigating toward a target place. When one is trying to figure out how to get to a new location, and is actively navigating along the way, there are two questions to constantly address. First, where are we now? Second, where should we go next? These two questions happen at the beginning and end of each lesson, as well as at major decision points that may arise during lessons.



Element 1: Looking Back

Each lesson begins and ends with reflection or looking back. The class asks, "What brought us to this point?" At the start of each lesson, the learning community needs to look back and remind themselves: Where are we in our mission? What have we accomplished? What's the main thing we need to work on now? What was our question? Oftentimes, instructional materials will prompt teachers or students to recall where the class left off. While this prompt is part of the Looking Back element in the Navigation Routine, there is an important difference. Although the teacher may have to start the conversation, the work of reflecting should be done by the students as much as possible. The purpose of reflecting is not simply to recap. It is to prime the pump so the class can think about, "Now knowing where we are, what makes sense to do next?" (Looking Forward).

Element 2: Looking Forward

After the class has a chance to look back, each lesson begins and ends with planning or looking forward. The class asks, "Where do we need to go next?" When the class looks forward, the students may identify a new question or direction to pursue with their teacher. Rarely in other instructional materials are students prompted to take part in articulating a logical next step to pursue. However, involving students in this work is critical for helping them develop into problem-solvers and positioning them as partners in figuring out how and why the world works.

Investigation Routine: Using Practices to Figure Out Science Ideas

What is it, and what is its purpose?

The purpose of the Investigation routine is to make sense of new investigative phenomena to support figuring out how or why the anchoring phenomenon occurred or to make progress on a design challenge. The class works with the questions or problems that led to this lesson, and engages in science and engineering practices to make progress, adding to explanations or solutions. This is the basic structure of the work of three-dimensional learning.

When is it conducted?

The Investigation routine is conducted throughout the unit in service of making sense of the Anchoring Phenomenon.

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

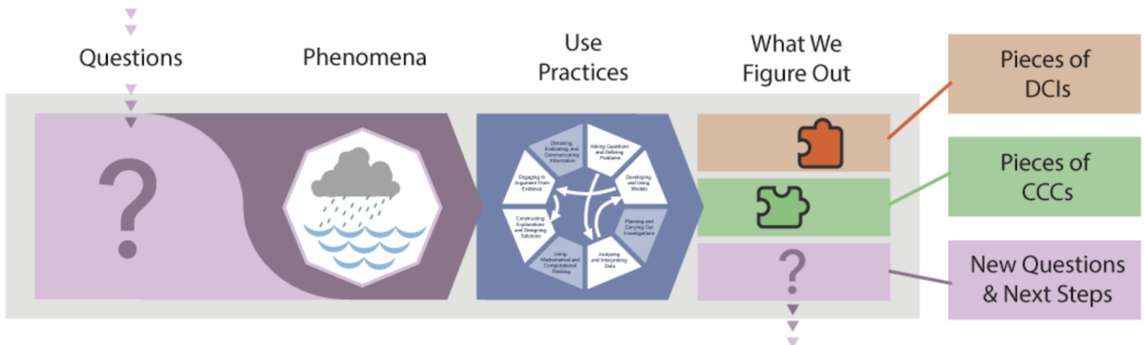
Students represent their thinking during Investigation routines in many different ways, including:

- Developing a plan of action
- Conducting experiments

- Exploring investigative phenomena
- Analyzing data from direct investigations or second hand datasets
- Evaluating data in light of current models, explanations, and designs
- Articulating new ideas and comparing them to current models

Typical Elements of the Investigation Routine

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



Element 1: Identify What the Class IS Trying to Figure Out and How to Make Progress

In the first element, the class works together to articulate and refine the question(s) about phenomena or a design where they need to make progress. Notice there is a yin yang symbol between the question and phenomena segments. This symbol indicates that the question and phenomena are tightly coupled. There is a column of arrows above the question block because oftentimes the question comes from the previous lesson, creating a need to engage in new phenomena. Or perhaps exploring new phenomena motivates the class to think of a new question. One can think of each step in the storyline as a step forward in knowledge-building, starting with a question arising from a phenomenon.

Next the class works together to determine a plan of action about that question. That plan could be as simple as identifying the general sort of data needed from an external data source to as detailed as planning the design of an experiment to conduct in class.

Examples of questions that guide the plan include the following:

- How much data do we need?
- What are some different types of measurements we would want to have reported?
- What variables do we need to measure and control?
- How are we going to record our observations?
- What do different components represent in the real world?
- What do we think might happen?

Element 2: Do the Work with Science and Engineering Practices

Students use science and engineering practices, such as carrying out investigations, analyzing data, modeling, and argumentation to make sense of a puzzling phenomenon, answer a question, or make progress on their explanations. The bulk of the class's time and energy is spent in this element. Students should be doing the heavy lifting of figuring out. Furthermore, that figuring out work should be in service of the mission the class has agreed to take on. IIf a visitor to the classroom were to ask students what they are doing at any moment during the activity, they should identify a phenomenon they are trying to figure out or a question they need to answer. Examples of using science and engineering practices can include the following:

- Collecting data through hands-on or computer simulations
- Analyzing graphs or data
- Examining and critiquing evidence
- Observing and manipulating physical models to explain phenomena
- Comparing how well competing models can fit and explain our data

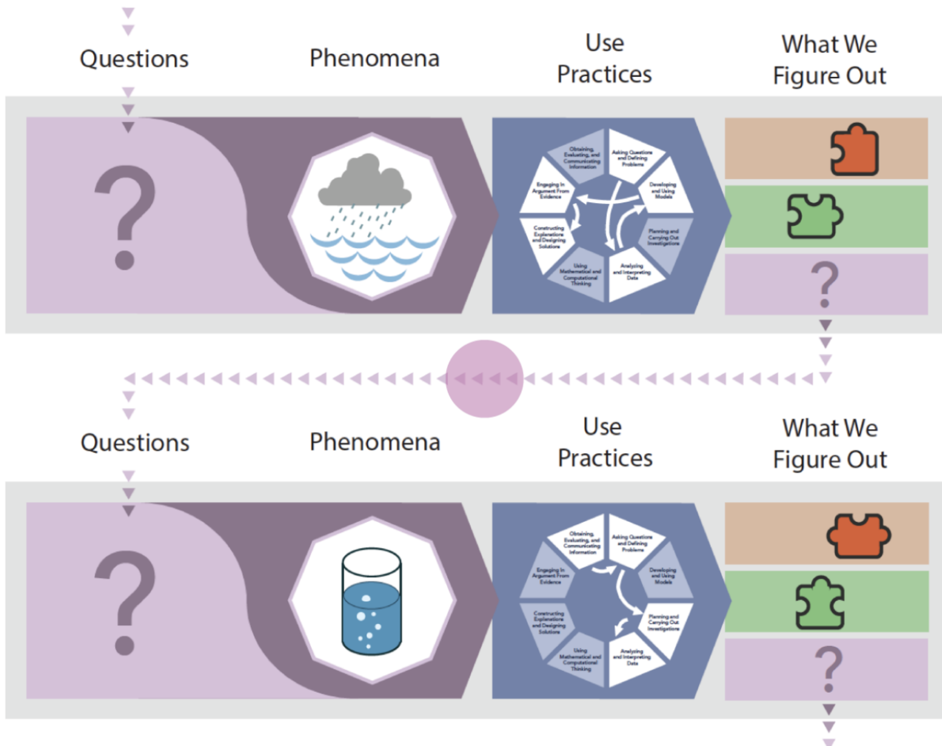
Element 3: Make Sense: What did we figure out?

At each step, students assemble another piece of the puzzle through the process of summarizing and synthesizing new information about a phenomenon. It might be a piece of a disciplinary core idea, such as the idea that a vibrating object can make sound. Students may also be extending their ideas of cross-cutting concepts, such as patterns or matter and energy. Notice that students did not learn about the science ideas first, and then engage in practices to use those science ideas to explain a phenomenon; it was the reverse. Students build the idea in the process of figuring out phenomena and problems. Examples of making sense can include the following:

- Revising or refining a model
- Participating in a discussion (e.g., expressing agreement or disagreement with the ideas or findings of others)
- Making a public record of our insights
- Connecting our discoveries to the Driving Question Board (e.g., Students ask, “How did it help us answer X question?”; this may overlap with the Navigation routine.)

Connected Investigations

Two interconnected routines, the Navigation and Investigation Routines, form Connected Investigations. The Navigation Routine provides the connections between investigations and helps the class take stock of where they are and where they want to head next. It helps the class bring a new question into focus and set a new trajectory for the next investigation. Coupling the Navigation and Investigation routines serves to support two types of coherence: WE figure out the pieces of the science ideas and WE decide our next steps. Together they are support Connected Investigations.

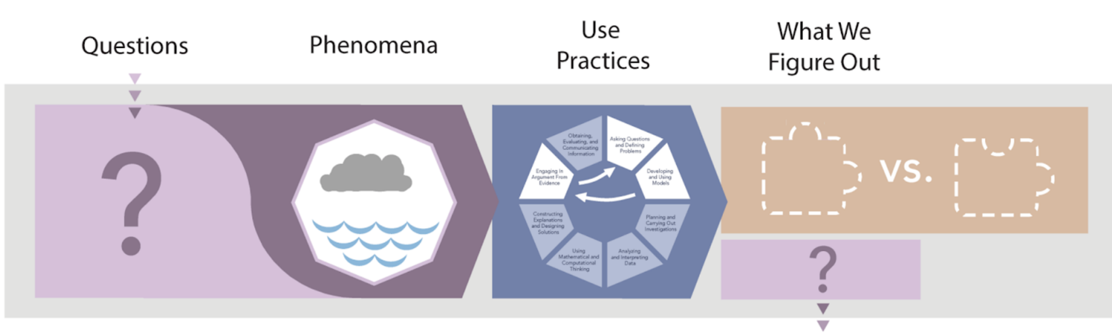


Storyline Tools #2 and #3 in the [Storyline Planning Tools](#) on the NextGen Science Storyline site provide planning templates for supporting the implementation of the connected investigations.

Problematizing Routine: Pushing Students to Go Deeper

What is it, and what is its purpose?

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



When is it conducted?

The Problematizing routine is often conducted after a Putting Pieces Together routine or at strategic locations in a sequence of investigations where we need students to recognize that there is more to figure out.

Typical Elements of the Problematizing Routine

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

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

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

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

In this section, the learning community attempts to really dig into the new puzzle and argue for their predictions or explanations. Students should try to come up with an explanation, model, or some other reasoning to explain why or how the phenomenon under investigation is happening. It's important that students try individually or in small groups to attempt to make sense and then go public with their ideas. A key part of this step is helping uncover where there are disagreements in applying the model so far, or to recognize that there are limitations in the explanation and unanswered questions. This step helps establish that there is a need to go deeper, and the classroom's work is not yet done.

Element 3: Pose Questions to Resolve and Discuss Next Steps

While we don't need students to articulate the detailed design of every investigation, in a coherent storyline we want the students to know why we are conducting a particular investigation and be a part of that thought process. Here, the class makes a joint list of questions and action items to accomplish their new mission. An example sequence of this element follows:

- The teacher asks, "What exactly is the disagreement we are having?" "What have we just figured out are the gaps what our model can do?
    - Students write individual questions.
    - Students share questions aloud.
    - The class adds to the questions on the DQB.
- The teacher asks, "How can we resolve this disagreement or fill in the gaps?"
    - Students brainstorm investigations that could help them figure out their questions, and why the investigations might help.
    - Post their new ideas near the DQB.

Storyline Tool #4 in the Storyline Planning Tools on the NextGen Science Storyline site provide planning templates for supporting the implementation of problematizing routine.

Putting Pieces Together Routine: Assembling and Using the Science Ideas We Have Built So Far

What is it, and what is its purpose?

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

When is it conducted?

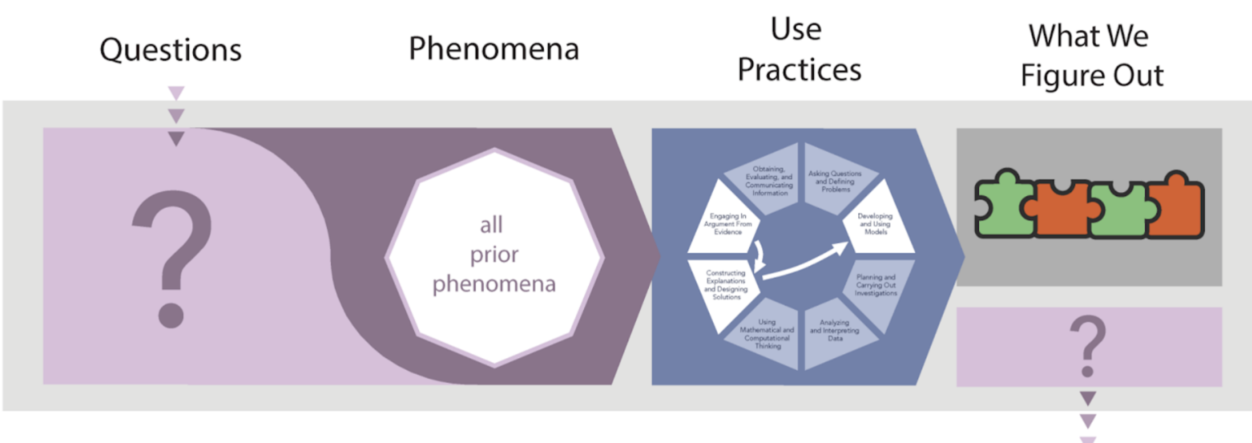
The Putting Pieces Together routine is conducted at strategic moments when students have synthesized evidence from a range of situations to construct an important component of the explanatory model. This routine is often used at the end of a lesson set and at the end of the unit.

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

Students typically represent their thinking through the following:

- A Gotta-Have-It Checklist
- A class consensus model or explanation
- A class of solutions to an engineering problem

Typical Elements of the Putting Pieces Together Routine



Element 1: Take Stock

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

Element 2: Put Pieces Together

The second element of the routine involves three parts:

a. Students attempt to put the ideas in the Gotta-Have-It Checklist to explain the phenomenon or design a solution, working individually first so that all students are given the opportunity to synthesize the evidence and formulate their ideas. This independent thinking is important so that all students are prepared to defend their ideas, evaluate one another's ideas, and consider their ideas in the context of other's ideas.

b. Students share and revise their ideas with a partner or in small groups to surface areas we agree we want to see represented in the class consensus model. This step is important to ensure that all students have the opportunity to articulate their ideas to someone else to help deepen their understanding, and to begin the process of students considering their ideas in the context of others' ideas. This partner or small group sharing also creates a safer space for students who might be less willing to participate in a larger setting. In addition, this talk time helps the partners or small groups identify ideas or features they want to bring to the class consensus model.

c. The class has a consensus discussion where students draw on their work to share and evaluate alternate models or explanations and to contribute to the Gotta-Have-It Checklist to explain a phenomenon or design a solution. During this process, the class develops a public representation of the ideas as they are putting them together, such as a diagrammatic model, a table showing commonalities across a series of cases, or a written explanation. The result is a revised class consensus model.

Element 3: Revisit the Driving Question Board

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

Element 4: Apply The Model or Explanation to Another Phenomenon (Optional)

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

F. How Can Teachers Use the Driving Question Board to Support Coherence?

The Driving Question Board (DQB) is a tool used in many NextGen Science Storyline units (as well as in OpenSciEd units) as a public representation of the questions the classroom community has developed. This public representation allows the class to use their questions to guide their work and to revisit and track questions that have been addressed. The driving question board approach draws on prior work from project-based science learning (e.g., Singer, Marx, Krajcik, & Chambers, 2000; Nordine & Torres, 2013; Weizman, Shwartz, & Fortus, 2010).

In a storyline, the DQB is a visual representation of the shared mission the class has developed. It is important that it be a public representation to serve as an organizer for the work the classroom community has committed to undertake. Teachers have developed various approaches to implement DQBs. For example, DQBs can be constructed with sticky notes, index cards, or sentence strips. They can be written on whiteboards or via shared software applications (e.g., Padlet). We encourage teachers to explore what works for their classrooms to develop a public representation of the questions the class has committed to investigate.

The Driving Question Board (DQB) is an essential tool for developing a sense of joint mission in a classroom learning community for any storyline. It should be used as a living artifact that the class can build on as a unit progresses. At any point in the unit, students should be encouraged to add more questions to the DQB.

It can be helpful to formally reflect on the DQB between learning sets to support coherence. After a learning set is complete, the class can return to the DQB for two reasons: (1) Identify which questions the class has made progress on and which ones are left. (2) Prioritize remaining questions to launch the next set of investigations.

Identify which questions the class has made progress on and which ones are left

Students find it motivating to celebrate the progress the class has made so far on answering their questions. One way to have students take stock is to have students read through all the questions on the DQB. Depending on class size, the teacher might type up all the questions on a piece of paper so students can read them at their desks. Then students use colored stickers to mark the questions they think they've made progress on. It's a very quick and visible way to see consensus around certain groups of questions. It also visually identifies the questions that students think are left over so the class can start to work through prioritizing remaining questions. The class can discuss the answers to those questions and even create a "Take away" board with the responses.

Prioritize remaining questions to launch the next set of investigations

The regrouping and prioritization of unanswered questions is a powerful tool to support coherence within a storyline. A physical reorganization of the remaining questions on the DQB can illuminate new patterns or insights and launch a new direction of investigations. Groups of questions can be categorized using sub-questions, topics or themes that the unit addresses. Once the remaining questions have been organized, the students should discuss which direction makes sense to pursue next.

Here are some discussion prompts that may be helpful for working with the DQB:

- Which of our questions are similar? What makes them similar?
- Which questions should we answer first? Why do those questions come first?
- How will answering those questions help us figure something out about the anchoring phenomenon?
- How will answering those questions help us solve our design challenge?
- We can't answer all of these questions at once, so which ones should we prioritize? Why are those questions important to answer, that is, why are they ones that might help us make progress on a larger set of related questions?

Places when it's useful to use the DQB

- At the beginning of a unit
- At the conclusion of a lesson set

- When the class is asking "What questions do we still have?" and "Where should we go next?"

Example of steps in a discussion around the DQB

- Elicit New Questions
- Clarify Meanings of Questions
- Discuss Significance of Questions
- Prioritize the Questions

G. How Can Teachers Support a Norm-Based Classroom Culture?

Purpose of Norms

Classroom norms play an important role in NGSS classrooms in general, and in NextGen Science Storylines classrooms in particular. The strategies presented in this section were developed through a collaboration of the OpenSciEd and NextGen Science Storylines development teams.[5] This work also draws from the work of the Science Education Research Partnership (SERP) and the Next Generation Science Exemplar Project (NGSX). Two specific resources include: Michaels, S. and O'Connor (2014). Establishing Norms: Laying the Foundations for Academically Productive Talk and O'Connor, C., Ruegg, E., and Cassell, C. (2017) Establishing Classroom Discussion Norms.

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

Norms to Support Productive and Equitable Participation

Respectful

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

[5] This section is adapted from the OpenSciEd (2019) Teacher Handbook, Section H.

can take place at the beginning of the school year, but also throughout the school year, to ensure that all students continue feeling supported and safe sharing their ideas in the classroom.

Equitable

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

Committed to our Community

We are working to "get smarter together." This means that WE learn together and it is not enough to just share our ideas without connecting to others' ideas. Establishing norms around being prepared and focused during discussions is important. Developing the ideas that we all have a responsibility to come prepared to our learning community, share our thinking so that others can understand, listen carefully, and ask questions is important. Encouraging students to contribute ideas even when they are not sure and celebrating ideas (both correct and incorrect) goes a long way in supporting these norms.

Moving our Science Thinking Forward

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

Important questions to consider:

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

Strategies for developing community norms

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

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

Tips for making norm-setting successful

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

Strategies for actively using and reinforcing community norms

- Help students understand rationale for norms. In the first few weeks using the norms, when pushing students to practice specific discourse moves, ask students to reflect on why you’re pushing them.
    - Why am I asking you to repeat what another student said?
    - Why am I asking for your reasoning?
    - Why is it okay to disagree with another student’s ideas? How does doing so move everyone’s science understanding forward?
- Lead a whole class check in. Discussing progress with the norms regularly helps students understand that norms are expected behavior all the time, not just in the beginning of the school

year, or when something has gone 'wrong.' Check in periodically with the class, asking students to reflect on:

- How did we do today in our discussion?
- What talk moves or norms do we feel we were successful with?
- What talk moves or norms do we need to work on?

- Do a partner check-in. At the start of class, have each student pick a norm they would like to focus on for the day and share that with a partner. At the end of the day, give partners time to share how they did with their focal norm. This elevates the community norms as students become more accountable for their actions, and helps students actively use and improve upon them.

Here is one approach to represent classroom norms developed by OpenSciEd, to provide a model for teachers to adapt in building norms with their students:

OpenSciEd Classroom Norms
(Reprinted with permission from the OpenSciEd Teacher Handbook)

Classroom Norms		Talk Moves to Support Norms
Respectful Our classroom is a safe space to share.	• We provide each other 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.	• "Daniel, that's a great idea. How do you think we could investigate it?" • Give time to think using wait time, turn and talk, or during individual writing time, such as Stop and Jot. • "Why do you disagree with Juan's idea?" rather than "Why do you disagree with Juan?"
Equitable Everyone's participation and ideas are valuable.	• We monitor our own time spent talking. • We encourage others' voices who we have not heard from yet. • We recognize and value that people think, share, and represent their ideas in different ways.	• "I'd like to hear from someone who hasn't yet gotten a chance to talk." • "How did we do today in our discussion making space to hear from everyone?" • "The way Shayna described _____ really helped me think about it in a different way."
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 everyone can hear.	• "Who can paraphrase what Selma just said?" • "What did your partner say?" • "What questions do you have for Shereen about her idea?" • "I think I heard what you said, but can you say it again to make sure everyone heard?"
Moving our science thinking forward We work together to	• We use and build on other's ideas. • We use evidence to support our ideas, ask for evidence from others,	• "Why do you think that? What's your evidence?" • "Do you agree or disagree with what Juan said? Why?"

figure things out.	and suggest ways to get additional evidence. ● We are open to changing our minds. ● We challenge ourselves to think in new ways.	● "Who can add onto Jerome's' idea?" ● "Did you see something represented in someone else's work that changes how you are thinking about _____?"

H. How Can Teachers Support Discussion?

The communication of scientific ideas is a central part of three-dimensional learning.[6] In three-dimensional learning, 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 also the way that a classroom community makes sense of what they are investigating. Finally, discussion is the key to a classroom learning community in which all students' ideas are shared and valued. In NextGen Science Storylines, 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 and NextGen Science Storylines units use specific types of discussions to help draw out student ideas, support students in communicating with one another in scientific ways, and support student sensemaking:

- Initial Ideas Discussions
- Building Understandings Discussions
- Consensus Discussions

Each type of discussion serves a different 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 ideas. Teachers are encouraged to set aside time for students to think individually and in small groups as part of a discussion plan.

Initial Ideas Discussions

Purpose

- To share students' initial ideas and experiences.
- To help students make connections between what they are learning in the classroom and what they have seen or experienced outside of school.

[6] Portions of the strategies in this section draw from tools and processes developed by NextGen Science Storylines project, the OpenSciEd Project, and from the Next Generation Science Exemplar System Project (NGSX) at Clark University and Tidemark Institute, from Science Teachers Learning from Lesson Analysis (STeLLA) project at BSCS Science Learning, and the work of the Investigating and Questioning our World through Science and Technology Project at the University of Michigan, Northwestern University, and Michigan State University. This material is based upon work supported by the National Science Foundation under Award Nos. 0310721, 0918277, 0957996, 1118643, 1220635, 1321242, 1503280, 1725389, and 1813127. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. This section is adapted from the OpenSciEd (2019) Teacher Handbook, Section I.

- To provide a chance to share and make sense of ideas, even if those ideas are tentative or still being formed.

When This Type of Discussion Is Useful

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

Strategies for This Type of Discussion

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

Building Understandings Discussions

Purpose

- To share, connect, critique, and build on others' findings, claims, evidence, and explanations.
- To provide the teacher and students with an opportunity to clarify which understandings emphasized in the storyline have been addressed and developed and which need further development

When This Type of Discussion Is Useful

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

Strategies for This Type of Discussion

1. Invite a student or group of students 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

Purpose

- To collectively work towards a common (class-level) explanation or model. This includes capturing the areas of agreement for which we have evidence as well as areas where we still disagree and might need further evidence.
- Take stock of where we are in our figuring out and support the public revision of earlier ideas.

When This Type of Discussion Is Useful

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

Strategies for This Type of Discussion

1. Ask students to take stock of where the class has been and what it has figured out, offering conjectures or pieces of a model, explanation, or solution.
2. Ask students to offer proposals for a consensus model, explanation, or solution.
3. Ask students to support or challenge proposed models, explanations or solutions and to say what evidence is the basis for their support or critique.
4. Ask students to propose a modification to the model, explanation or solution based on input from the class.

Making Participation Equitable During Discussions

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

- In eliciting initial ideas or initial questions, the goal is to get as many ideas on the table as possible. Consider asking students to "write and pass" a sheet of paper around their group until they have at least 10 items. That way, all students get a chance to contribute, to see others' ideas, and to add their thinking in a low-stakes way. Make sure to let students know that these ideas can be expressed in different ways (e.g, pictures, graphs), and that they are not limited to words in English.
- Use student groups' feedback to prioritize ideas and questions for the class investigations. For example, have groups pass their written lists to another group, who circle the two "most pressing questions" on the list. As they do this, you can circulate and find the top four or five questions—this is your final student-generated list of driving questions.
- Think about what kinds of support your students might need to be able to ask each other to clarify and summarize questions without being critical or evaluative. You might try using the metaphor of a coach to introduce these think-pair-share routines. You could try telling students, "This is about helping your partners practice as 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 sideline. Then we'll switch, and you'll get a chance to share your ideas as you are coached by your partners."
- Have sentence starters available for students so that they know what they might ask to push their partners further (e.g., "You mentioned____, can you say more about that?), but also have sentence starters available to slow down the fast explainers (e.g., "Wait—you said that really fast. Can you say that again?")
- Consider a variety of ways for students to have these discussions, such as in a gallery walk where one person stays by the group's model, explanation, or solution, to invite and respond to critique,

while other students ask pressing questions. During critique-based interactions, it is important to emphasize "making our ideas stronger," not "showing we have the best ideas" and that it is important to critique the idea, not the person. You can also encourage students to take a "coaching" stance here: their role is to ask questions that support others' ideas and to encourage other students to speak up when something needs to be clarified or repeated.

- Many students are not comfortable being the "only one" who voices a disagreement, a discontent, or a potentially wrong idea, so ask students to use the think-pair-share routine and to carefully listen to their partner's ideas. Then ask students to think about what they heard their partner saying, and ask the room if their partner's ideas are represented in the class discussion. This strategy 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.

Questioning Strategies to Support Discourse

To engage students in these types of discussions, OpenSciEd and NextGen Science Storyline units suggest four questioning strategies for teachers to use to promote student discourse. These questioning strategies are intended to surface, challenge, and move forward student thinking while also fostering a community of science learners. While they are initially intended as questions that teachers can use, if they are incorporated as part of the norms of classroom culture, students will also begin asking these questions of each other.

These questioning strategies are (1) elicit questions, (2) probe or clarify questions, (3) challenge questions, and (4) support science discourse questions.

Elicit Questions

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

Examples of elicit questions include:

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

Probe or Clarify Questions

The purpose of asking probing questions is to get more information about a student's thinking and understanding. It is not designed to teach new ideas or to "lead" students to a correct answer. Such questions can ask the student to give more information ("Can you tell me more?") or they can ask a student to clarify 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 probe or clarify 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?

Challenge Questions

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

Examples of challenge questions include :

- 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?

Support Science Discourse Questions

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. 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 reinforcing this type of communication to students 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?

Discussion Planning and Reflection Tool

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

Before the discussion:

1. What is the question students are trying to answer through this discussion?
2. What is the intended outcome of the discussion? (e.g., coming to consensus on something 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?
4. What other ideas might students have? What questions might they ask?
5. Where will you be going next and how will this influence how you wrap up the discussion? (e.g. problematize? continue investigation? design an investigation? apply ideas back to the anchor?)

Leading the discussion

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

After the discussion

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

5. Is there anything you would do differently if you could do the discussion over?

I. How Can Teachers Support the Development of Scientific Language?

Developing scientific language is an important aspect of engaging in science practices[7]. Communicating explanations, critiquing explanations and models, and many forms of scientific discourse require developing new ways of using language. Yet there has been some confusion in the field about the best approaches for developing scientific vocabulary in the era of NGSS. On the one hand there are no specific vocabulary targets outlined in NGSS or in the *Framework for K-12 Science*. The Framework specifically argues for the importance of recognizing that students may have scientifically sophisticated reasoning, and be able to apply a scientifically accurate model that draws on disciplinary core ideas, *without* having all the technical scientific language that labels these elements. Assessment guidelines for NGSS emphasize not mistaking having the right vocabulary word with understanding the concept, and not mistaking the lack of a vocabulary term with the lack of understanding of the science idea (National Research Council, 2014). That is, knowing the technical science term is neither necessary nor sufficient for demonstrating mastery of a disciplinary core idea.

On the other hand, scientific language can help us engage in more precise articulation, critique, and revision of ideas. There is certainly a place for technical scientific language in three-dimensional learning.

The problem arises, however, when the science term itself becomes the focus rather than the disciplinary core idea. In particular, the problem arises with instructional approaches that emphasize the role of introducing and defining key vocabulary before helping students develop and reason about the ideas. Research on the role of language in science does not support the effectiveness of approaches such as pre-teaching science vocabulary (National Academies of Science, Engineering, and Medicine, 2018).

The research on science and literacy advocates introducing scientific language to attach to and help make more precise (rather than precede) the science ideas students are building. Vocabulary in NextGen Science Storylines is used so that it does not undermine the heavy lifting we want to engage students in during their day to day work in the classroom. In each lesson we want students engaging in practices around a question that they feel a genuine drive to figure out. Front loading vocabulary often gives away the punchline for that lesson that is connected to the meaningful insights and discoveries that students are working toward figuring out.

When *all* students have developed a conceptual understanding of an idea in a lesson, introducing a relevant scientific term can be a useful tool. At that point it can provide the shorthand way to reference an idea that the class developed together and now makes sense to refer to in a more abbreviated manner. Introducing a vocabulary word to refer to a concept the class has already been developing and discussing requires bringing it in "just in time."

This sort of "just in time" academic vocabulary building doesn't undermine the sense-making of students, nor defeat the goal of figuring out important science ideas in each lesson. We want to give them a rich opportunity and experience to wrestle with developing these important science ideas before introducing vocabulary to represent an abbreviated description of those ideas.

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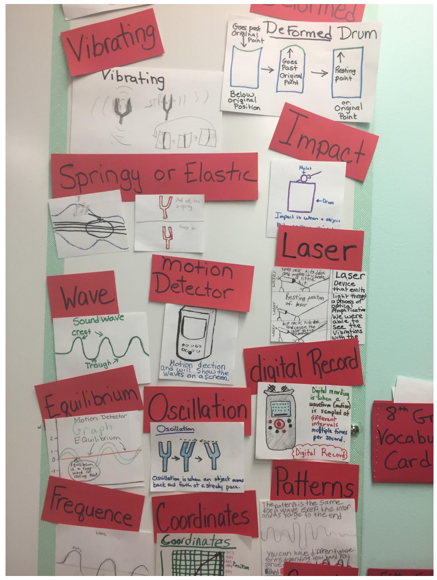
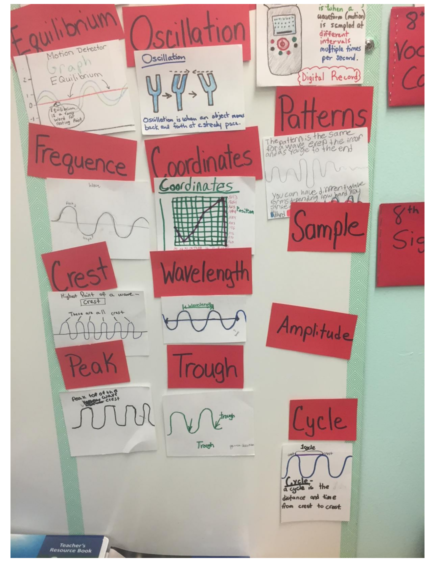
[7] Portions of this section have been presented in the front matter of the 2018 NextGen Science Storyline, *How Can We Sense So Many Different Sounds From A Distance?* [v2.1].

Key scientific terminology to connect "just in time" as a lesson unfolds is identified in every Teacher Guide. Teacher Tooltips in the Learning Plan describe when to introduce many of these words.

As new scientific terminology is developed with the class, teachers can build a word wall of these ideas. Keeping a visual model next to each word can help students recall the concept the word is associated with. A set of student-built word cards for a teacher's word wall is shown to the right, for a middle school storyline on sound.





J. How Can Teachers Support Differentiated Instruction?

The differentiation approach described here was developed through collaborations of the Inquiry Hub (Severance et al, 2016), NextGen Science Storylines, and OpenSciEd projects.[8] This approach draws on principles of Universal Design for Learning (UDL; CAST, 1998). UDL calls for curriculum designers to create materials for the widest possible range of learner capabilities that are usable as is or with limited modifications. To this end, NextGen Science storyline units include multiple modes of representation of content, through text, image, video, and sound through which students can access ideas. The units provide opportunities for different forms of expression, in speech, writing, drawing, and in manipulating computer models. Finally, there are multiple modes of engagement through the eight science and engineering practices.

There are several strategies embedded in the NextGen Science Storyline units that support differentiation. Summary charts are one important strategy. At the end of most lessons, the teacher guide prompts the teacher to have the class co-construct a summary of the big ideas that they figured out either on a class summary chart or poster or in an individual progress tracker. Both of these resources serve as a useful "single stop" location for students to look to review the big ideas they will use in future assessments. Teachers can encourage students to return to referencing either of these resources during summative assessments. For students who are seeking a challenge, teachers can encourage them to do these assessments first without using a reference, such a class summary chart, posters, or progress trackers.

Additional information throughout the units include references to differentiating activities for students with special needs, to provide extensions for high-achieving students as well as modifications for students who need extra support. These are built in as teacher support box on the right hand column of the Learning Plan for every Teacher Guide in every lesson, and have an icon marking them for Differentiation Support:

[8] Portions of this section have been presented in the front matter of the Inquiry Hub / NextGen Science Storylines unit *Why Don't Antibiotics Work Like They Used To?* [v3.1], the front matter of the 2018 NextGen Science Storyline, *How Can We Sense So Many Different Sounds From A Distance?* [v2.1], and the OpenSciEd *Teacher Handbook* (2019).

Differentiation Support

For high-achieving students, the use of a Driving Questions Board provides a basis for independent investigations related to the anchoring phenomenon that allow these students to contribute to the class while exploring novel questions related to their own interests.

Some lessons also provide different options for the use of student home learning assignments.

Acknowledgements

This handbook represents a synthesis of ideas, strategies, and resources developed across the science education community. Many of the ideas in this handbook were developed in part in collaboration with the development teams of BSCS Learning, OpenSciEd, and the Inquiry Hub, and continually refined through the work of one or more of these projects.

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