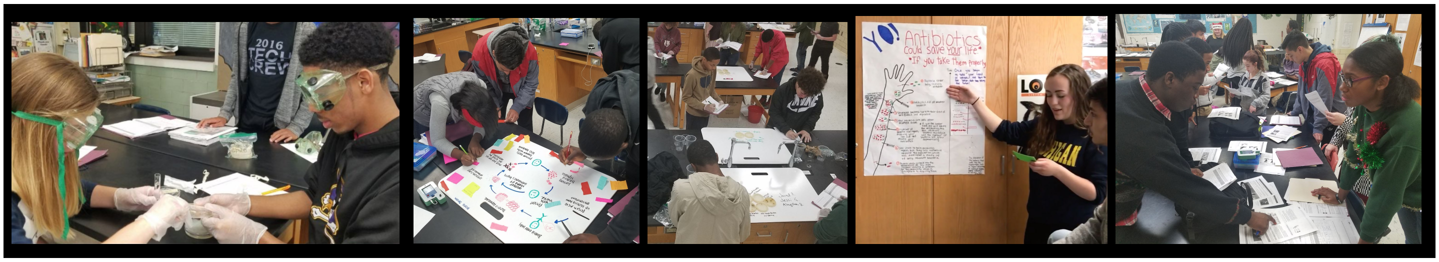
Why Don't Antibiotics Work Like They Used To? (v3.1)

NGSS High School Evolution Unit

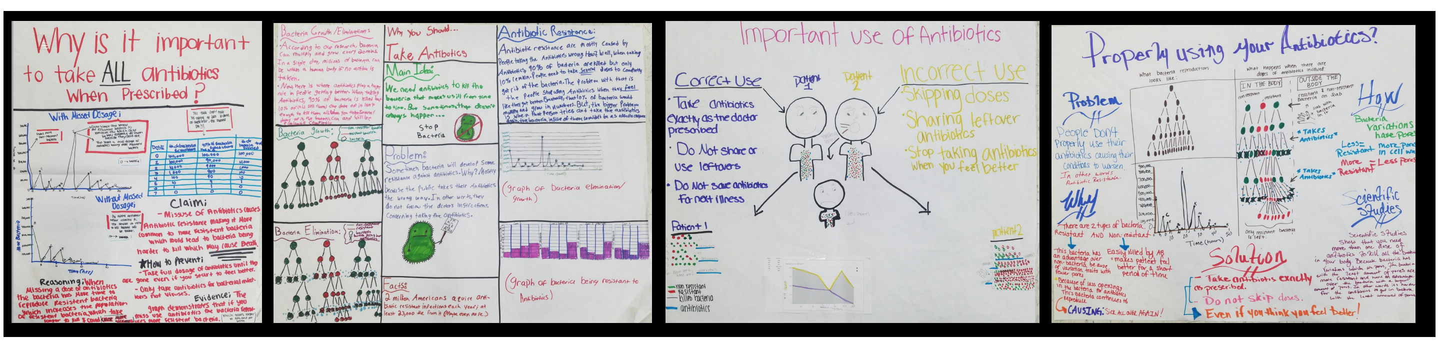


Synopsis *In this high school unit on evolution, students initially investigate the case of young girl with a life-threatening infection of pan-resistant bacteria. This case sparks questions that lead them to investigate the growing prevalence of such cases and the discrepancies between antibiotic use in their communities and CDC recommendations. They expand their investigations to look at population changes occurring in a population of birds (juncos) which exhibit noticeable differences in physical and behavioral traits from the past 60 years.*

NGSS PERFORMANCE EXPECTATIONS BUNDLE		
Natural Selection and Evolution		
HS-LS4-1	HS-LS4-2	HS-LS4-3
HS-LS4-4	HS-LS4-5	

- *By investigating objects where bacteria can be found in their school, students figure out how bacteria reproduce. What students figure out from this helps answer their initial questions about where we can pick up bacteria and how we can remove it.*
- *By testing how E.coli and ampicillin interact with each other on a petri dish, students gather evidence for how a bacteria population become more resistant over time. What they figure out from this helps answer their initial questions about how antibiotics affect bacteria.*
- *By conducting investigations with computational models, students develop a model for how competition and competitive advantage can lead to shifts in the distribution of traits in a population over time. What they figure out can help explain what happened in the young girl's case, as well as the growing prevalence of pan-resistant bacterial infections over time.*
- *By analyzing data of how juncos react to humans in the wild and in common garden experiments, students figure out the relationships between the physiological and behavioral differences in the birds. What they figure out helps answer their initial questions about whether behavior can be inherited.*
- *By analyzing data of how juncos react to seasonal changes, students figure out how physiological changes can be triggered by changes in the environment. What they figure out helps them answer their questions about what led the ancestors of the juncos to split into two separate descendant populations.*
- *By comparing mtDNA and allele frequency data from populations of juncos across North America, students figure out how geographic and reproductive isolation can contribute to speciation and adaptation. What they figure out helps them answer their questions about why different looking juncos are found in different environments.*

This unit illustrates how we can help students extrapolate a general model for science ideas (evolution) out of exploring case studies, rather than teaching them the science ideas first and then seeing the ideas in action by looking at examples.



These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

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Development History:

- Design team starts work on v1.0 version of storyline (summer, 2015).
- v1.0 of storyline piloted (school year, 2015-2016).
- Design team expanded and v2.0 developed (spring and summer, 2016).
- v2.0 piloted (2016-2017).
- v2.0 of storyline developed and sent to Achieve (Jan., 2017).
- Design team expanded and v3.0 developed (summer and fall, 2017).
- v3.0 piloted (2017-2018).
- Design team updated v3.1 (winter 2018)

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Table of Contents

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A. What Is This Unit About?

This high school unit on natural selection and evolution starts out with students exploring the case of a young girl with a life-threatening infection of pan-resistant bacteria. This case which serves as the anchoring phenomenon for the unit sparks questions that lead students to investigate the growing prevalence of similar cases and the discrepancies between antibiotic use in their communities and CDC recommendations. This can motivate students to take on an optional citizen science mission to figure out why this is happening, and to help develop infographics to sway individual health choices related to the (mis)use of antibiotics.

Their investigations lead students to design experiments and develop and use mathematical and computational models to figure out where bacteria are found, how bacteria grow and compete for resources, and how antibiotics interact with bacteria. They develop a model for how interactions between heritable variations in bacteria and environmental changes can lead to the emergence of more resistant populations of bacteria over time.

Students use the model they developed (of natural selection) to return to the anchoring phenomenon of Addie that launched the unit, to explain the growing prevalence of antibiotic resistant bacteria in hospitals and their communities over time, and to inform the development of the infographic to share with health service providers and community members. Students then identify criteria for a model organism, in an effort to determine the extensibility of their model for explaining other types of changes occuring in populations other than bacteria.

The case students explore next is a group of juncos that have changed rapidly over the past 60 years. One population of juncos that lives on the UCSD campus exhibits bold behaviors and unique physical traits that distinguish it from its mountain cousins. This phenomenon sparks questions about whether these differences in behavior are learned or inherited, what led to differences in mating and migration patterns, and what led to the different physical trait variations.

Investigations into the environmental changes that have occured on campus, common garden experiments, and the physiology of the birds lead students to develop an explanation of the juncos using a natural selection model again.

This explanation raises new questions about why some, but not all, juncos settled on the campus in the first place, whether the UCSD juncos are now a separate species, and whether this sort of separation and differentiation has occured at other points in time. This leads students to investigate the physiology of juncos further and where other juncos are found across North America. Students develop methods for comparing genetic differences between populations to determine if different populations of juncos are the same species and how long ago they diverged from a common ancestor. In this process, they uncover the role of non-random mating, migration, and mutation in contributing to evolution of populations over time.

Students culminate their work in this storyline, arguing that their model of evolution applies to all life on Earth, including bacteria and humans. They investigate how environmental changes over time have contributed to the emergence of new species and the extinction of others.

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B. What Is a Storyline?

This unit is a storyline. A storyline 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. A student's 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, to help figure out a scientific idea. Each piece they figure out should add to the developing explanation, model, or designed solution.

Each step may also generate new questions that lead to the next step in the storyline. Together, what students figure out helps 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.

Often the importance of a particular problem or idea is clear to the teacher, but not to the students. For example, the teacher knows how learning about the cell will help with important biological questions, but to the students, they are learning about cells because that's the title of the current chapter in the textbook. The teacher may know how a particular chemistry experiment will help understand something about conservation of matter, but to the students, they are doing the experiment because they are following the directions.

In a storyline, the coherence is designed to make sense from the students' perspective, not just the teacher's. When a storyline is coherent from the students' perspective, on any given day, a visitor to the classroom should be able to walk over to a group of students and ask them:

- What are you working on?
- Why are you working on this?

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 the teacher told them to do this. They should be able to explain how they helped the classroom community decide a plan of action.

Figuring out is not a process you 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 when to wear goggles. 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.

So each storyline is a path in which all 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 a question or gap in the classes' 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.

So, how will WE orchestrate our sensemaking? The answer is a storyline. The bottom line is that a storyline reflects a way to support sensemaking that is coherent from the students perspective.

This unit is a storyline that illustrates how we can help students extrapolate a general model for science ideas (evolution) out of exploring case studies, rather than teaching them the science ideas first and then seeing the ideas in action by looking at examples. The performance expectations that this unit helps students develop mastery of are shown in the next section.

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C. What Performance Expectations Does This Unit Target?

Targeted NGSS Performance Expectations:
• **HS-LS4-1:** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. • **HS-LS4-2:** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. • **HS-LS4-3:** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. • **HS-LS4-4:** Construct an explanation based on evidence for how natural selection leads to adaptation of populations. • **HS-LS4-5:** Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Connections to Middle School NGSS Performance Expectations:
• **MS-LS4-1:** Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. • **MS-LS4-2:** Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. • **MS-LS4-4:** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment. • **MS-LS4-6:** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

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These are the related science and engineering practices, disciplinary core ideas and cross-cutting concepts that the storyline helps students develop and use:

Targeted Scientific Practice(s)	Targeted DCI(s)	Targeted Cross-Cutting Concept(s)
Obtaining, Evaluating, and Communicating Information ● Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-LS4-1) **Constructing Explanations and Designing Solutions** ● Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2) (HS-LS4-4) **Analyzing and Interpreting Data** ● Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3) **Engaging in Argument from Evidence** ● Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5) - - - - ***Connections to Nature of Science*** - - - - - **Scientific Knowledge is Based on Empirical Evidence** ● A scientific theory is a substantiated explanation of some aspect of the natural world, based on facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-LS4-4)	**LS4.A: Evidence of Common Ancestry and Diversity** ● Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1) **LS4.B: Natural Selection** ● Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-3) (HS-LS4-4) ● The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3) **LS4.C: Adaptation** ● Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3) (HS-LS4-4) ● Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) ● Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5) ● Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5) ● Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)	**Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2)((HS-LS4-4)(HS-LS4-5) **Patterns** ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1)(HS-LS4-3) --- ***Connections to Nature of Science*** ---- **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ● Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-1)(HS-LS4-4)

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D. How Long Is This Unit?

There are two bends, or parts, to this storyline. Bend 1 is designed to precede Bend 2. Some teachers choose to implement one, instead of both bends. The teacher guides are written to support implementation of both bends.

Calendar for Planning Implementation: Each period is assumed to be 50 minutes in length

Bend 1 - Addie

Three options for implementation are outlined below.

- **Option A**: This is the full bacteria plating option. Students will conduct all bacteria plating experiments [3a, 3b, 8a, 8b, and 8c] and use stericycle waste bio removal service to dispose of sealed results.
- **Option B:** This is the partial bacteria plating option. Students will conduct only the bacteria plating experiments from known sources [8a, 8b, and 8c] (*E.coli* from BioRad).
- **Option C:** This is the no bacteria plating option. Students will analyze photographs from other classrooms that conducted plating experiments.
- **Mission Board**: This is doing the Mission Board as an alternative activity and assessment which will culminate in Alternative Lesson 13: Mission Board.

Lesson #	Length in periods (50 minutes)			
	Option A	Option B	Option C	Mission Board
1	2	2	2	
2	2	2	2	
3a*	2	1	1	
4	1	1	1	+1
3b	1	1	1	
5	1	1	1	
6	1.5	1.5	1.5	
7	1	1	1	.25
8a	1	1	.75-1	
9	1	1	1	
10	2	2	2	
8b	1	1	.75-1	
11	2	2	2	
8c	1	1	.75-1	+.25
12	1	1	1	
13	2	2	2	+1 (alt. to L13)
Total	22.5-23	21.5-22	20-21.5	+2.5

*The letters after a lesson indicate a continued lesson that has to span over multiple days. For example, Lesson 3b is a continuation of the experiment from Lesson 3a, but because it takes time for bacteria to grow, we suggest doing Lesson 4 in between.

Bend 2 - Juncos

Only one option is outlined for the second half of the storyline (Bend 2).

Lesson #	Length In periods
14	1
15	2
16	2.5
17	1.5-2
18	2
19	1
20	1
21	1
22	2
23	0.75-1
24	1
25	1
26	1
27	2
28	1.5
29	2.5
Total	23.75-24.5

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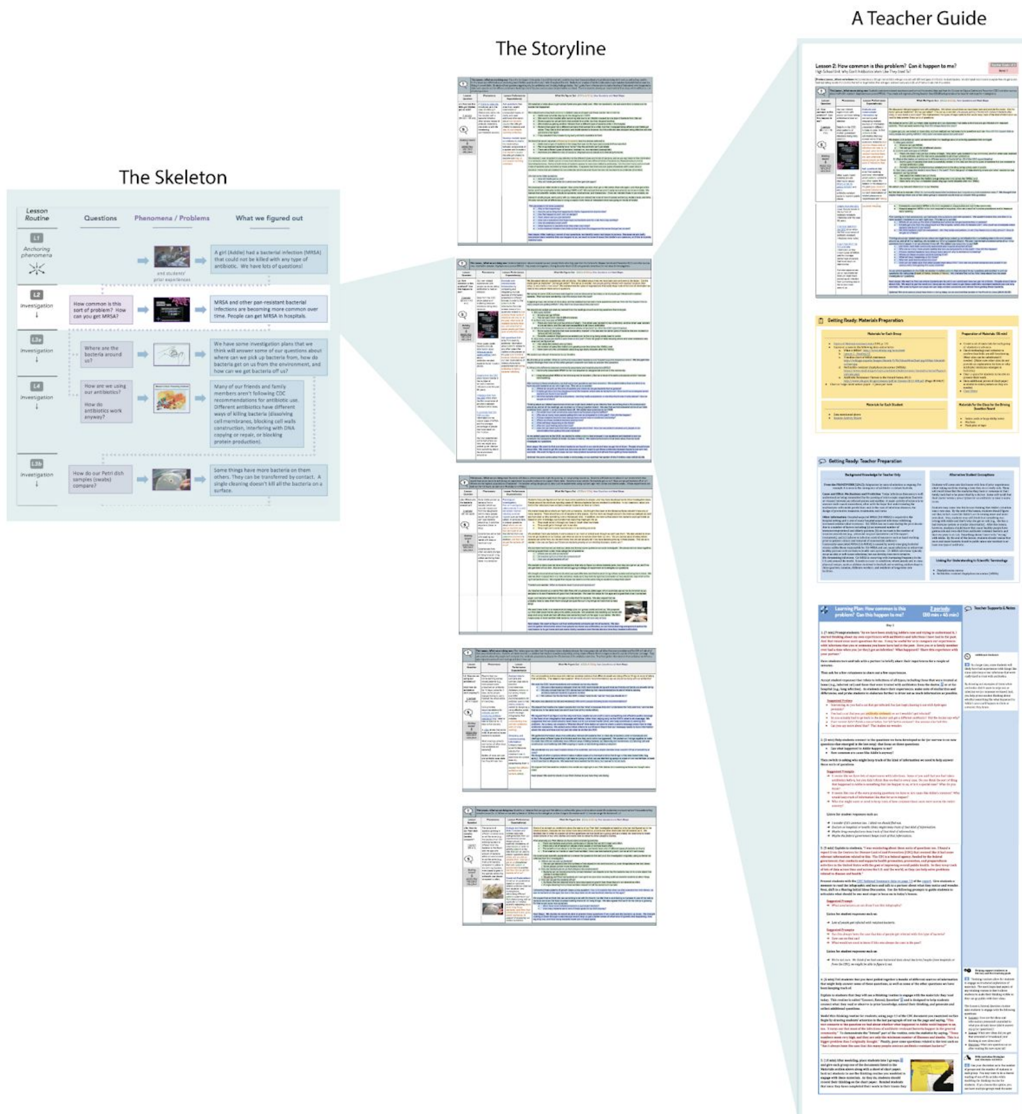
E. What Unit Planning Resources Are Available?



There are three main unit planning resources available; the skeleton, the storyline, and the teacher guides. As suggested in the diagram to the right, each of these resources, provides progressively finer detail about what is in a particular lesson.

The skeleton includes the question that students will investigate in each lesson and photo/diagram of one of the related phenomena they will investigate in that lesson. It also includes a two to four sentence summary of what students figure out for that lesson. In the diagram above, this portion of the skeleton shows this for the first five lessons of the unit.

The storyline provides a more detailed description of what students will investigate in each lesson, with each lesson summarized in its own table. Each table is 1-2 pages in length, and is referred to as the roadmap for that corresponding lesson. Each roadmap includes lesson level performance expectations, connections to the previous lesson and the next, and a more detailed narrative of what the class is doing in that lesson. In the diagram above, the first five roadmaps in the storyline are shown.

Every roadmap has a corresponding teacher guide. The first few pages of the teacher guide include the roadmap for that lesson, background information for the teacher and a learning plan. The learning plan provides a minute-by-minute guide to help the teacher coordinate and facilitate the learning activities. Additional details about these and other supports included in each lesson plan are summarized on the next page.

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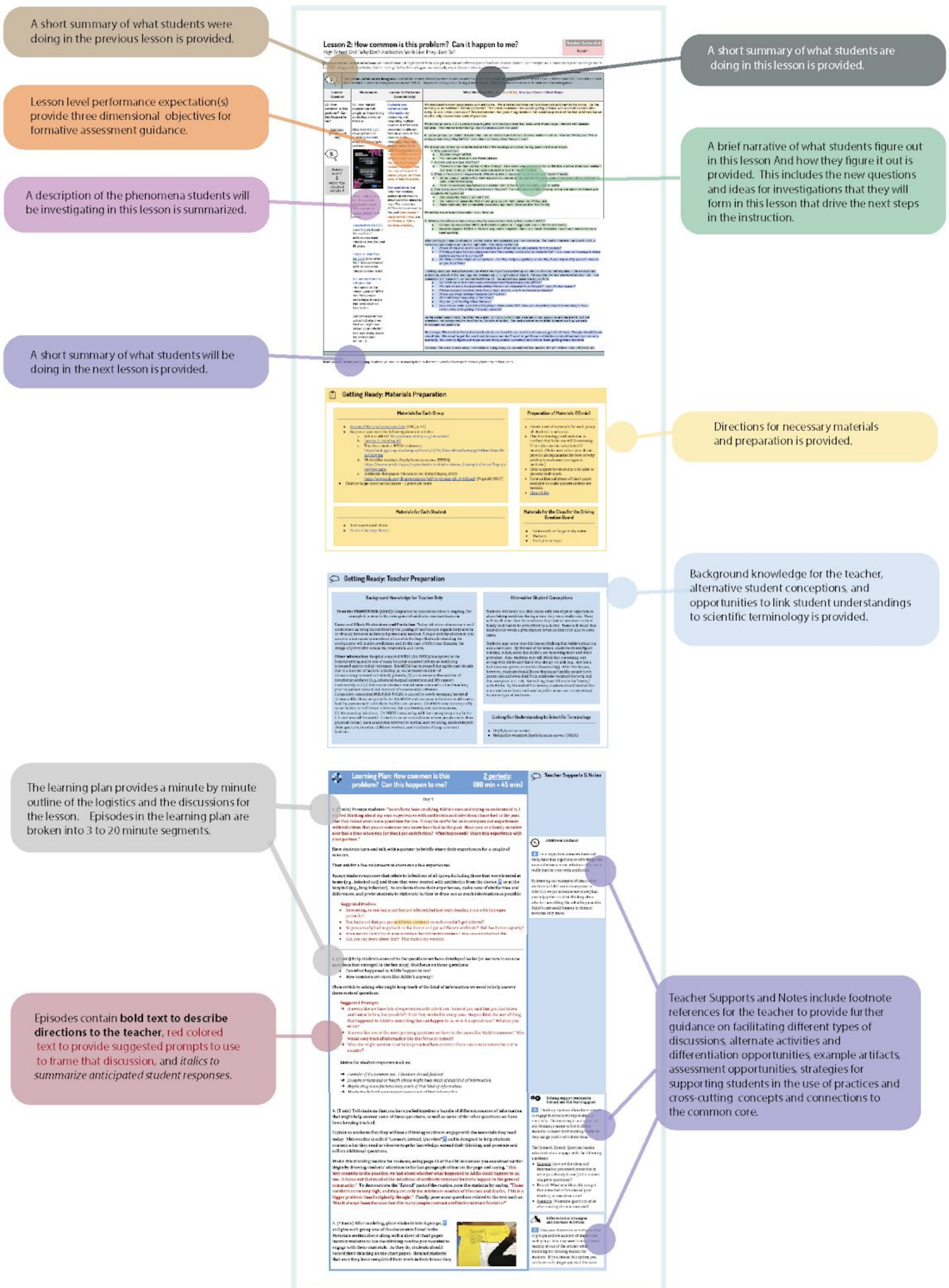
F. What Lesson Planning Resources Are Available?

Each Teacher Guide for every lesson has a similar structure, which is outlined in the example shown below. Each lesson may include additional resources, such as student activity sheets, data packets, video clips, readings, home-learning assignments, and projected images. All related resources for the lesson will be referenced in the Materials Preparation section of the Teacher Guide.



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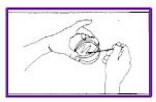
G. What Do Students Investigate and Figure Out in Each Lesson?

The diagrams on the next six pages outline the sequence of lessons for the unit. It is referred to as the unit skeleton.

Lesson Routine	Questions	Phenomena / Problems	What we figured out
L1 Anchoring phenomena		 and students' prior experiences	A girl (Addie) had a bacterial infection (MRSA) that could not be killed with any type of antibiotic. We have lots of questions!
L2 Investigation	How common is this sort of problem? Can this happen to me?		MRSA and other pan-resistant bacterial infections are becoming more common over time. MRSA can been found in lots of public places.
L3a Investigation	Where are the bacteria around us?		We can pick up bacteria from many of the places we interact with every day. A single application of antiseptics does not kill all the bacteria on us or on a surface.
L4 Investigation	How are we using our antibiotics? And, how do antibiotics work anyway?		Many of our friends and family members aren't following the CDC recommendations for antibiotic use. Different antibiotics have different ways of killing bacteria (dissolving cell membranes, blocking the construction of cell walls, interfering with DNA copying or repair, or blocking protein production).
L3b Investigation	How do our Petri dish samples (swabs) compare?		Bacteria grew really fast on the food in the Petri dishes. There are variations in the size and color of different spots of bacteria.
L5 Investigation	How do bacteria grow?		A bacteria colony is made of many bacterium cells. When the colony grows, some of bacterium are growing in size and then splitting in half producing two bacteria. This type of reproduction can occur every 20 min. It leads to exponential growth.

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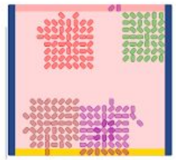
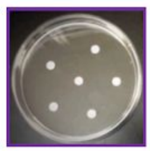
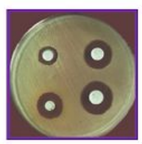
Why Don't Antibiotics Work Like They Used To? (v3.1)

NGSS High School Evolution Unit

Lesson Routine	Questions	Phenomena / Problems	What we figured out
L6 *Investigation*	Will the bacteria on our Petri dishes continue to grow this quickly forever?		Bacteria compete for limited resources, which limits their population growth. Competition for resources can affect the distribution of trait variations in a population. This can explain some of the patterns of growth we saw in our Petri dishes.
L7 *Investigation*	How do bacteria get killed?		It can take multiple doses of antiseptics or antibiotics to kill 100% of the bacteria in a population. Some bacteria might actually be different from the others; even though some antibiotic particles interact with these bacteria, they don't kill them.
L8a *Investigation*	How do antibiotics affect bacteria when they are put together (in a Petri dish)?		Antibiotics partially diffuse through the agar, leading to some spots where it is more concentrated than others.
L8b **L8c** *Investigation*	What's happening with our antibiotic experiment?		The zone of inhibition gets progressively smaller with each additional dose and new replating.
L9 *Putting pieces together* / *Problematizing*	What's happening inside Addie?	Previous phenomena from L1 through L7	We pulled together what was happening across three different systems (Addie, our Petri dishes, and the simulation). We identified additional objects and interactions to include in a revision to the simulation to help us explore some of the phenomena we still had questions about.
L10 *Investigation*	How do different doses of antibiotics affect a bacteria population in a simulated infection?		Individual bacteria that have an advantageous trait variation, like fewer pores, have a better chance of surviving exposure to antibiotics, than those without that variation.

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Lesson Routine	Questions	Phenomena / Problems	What we figured out
L11 *Investigation*	How does moving bacteria that survive antibiotic doses from one environment to another affect the population over time?		Individual bacteria with trait variations that allow them to survive exposure to antibiotics, reproduce. Over time this leads to a shift in the distribution of traits in bacteria populations, so that those variations become more prevalent over time.
L12 *Putting pieces together*	How did the bacteria population become more resistant in Addie and in our community?	Previous phenomena from L1 through L11	The same interactions and outcomes in the simulation were also at work in Addie's body and also at work in our community over the past ninety years. Bacteria populations became more resistant to being killed by antibiotics as trait distributions in the population that granted them a competitive advantage for survival became more prevalent over many generations of exposure to antibiotics.
L13 *Putting pieces together*	How can we use what we figured out to complete our mission (help change health practices in our community)?	Previous phenomena from L1 through L12 and our citizen science mission from L4.	We can help our community fight (or slow) the increasing frequency of antibiotic resistant bacterial infections by communicating a more effective message (than the CDC) for why people should follow CDC recommendations regarding antibiotic use.
L14 *Problematizing*	Which aspects of our natural selection model apply to other organisms?	All previous phenomena from L1 through L11.	We identified characteristics we wanted in a new case to help us evaluate whether the interactions and outcomes of our model for how bacteria populations change over time (natural selection) can be used to explain changes observed in other populations of organisms.

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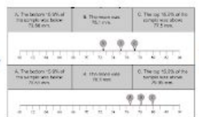
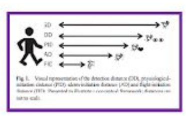
Lesson Routine	Questions	Phenomena / Problems	What we figured out
L15 Anchoring phenomena	What is happening in this new case of the UCSD and mountain juncos?		Juncos normally migrate to the CA coast for the winter and back to the mountains in the summer. Something happened 40 years ago, that led a group of them to stay on the UCSD campus year round. Both populations of descendants (UCSD and mountain juncos) now look and act different from one another.
L16 Investigation	Just how different are these juncos from one another?		There are measurable differences in the tail length, wing length, and the amount white in tail feathers, found between individuals within each population and in the distribution of variations found between populations.
L17 Investigation	How are physical traits like wing color or wing length inherited?		Many trait variations seen in birds, like feather colors, feather patterns, and limb proportions are the result of the combinations of alleles that were inherited. These provide instructions to the cells of the organism about what substances (proteins) to produce or not produce.
L18 Investigation	Just how different is the UCSD birds' behavior?		The UCSD Juncos have become bolder than their mountain relatives over a few generations.
L19 Investigation	How do scientists tell if a behavior trait is learned or inherited?		We can test if a behavior is inherited or learned by taking some individuals born into one environment and raising them in a different environment and seeing what traits change and which ones stay the same.

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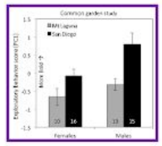
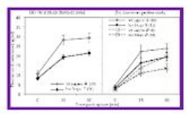
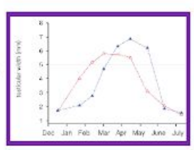
Lesson Routine	Questions	Phenomena / Problems	What we figured out
L20 Investigation	Do the juncos just learn to be bolder or is their behavior something they inherited?		Exploratory behavior in juncos is inherited. Alleles that are or are not inherited can influence what substances are or are not produced by cells in any living creature. We think this might be what is causing differences in their behavior.
L21 Investigation	Are there differences inside the birds that would explain why they behave differently in response to things happening around them?		In stressful situations the amount of stress hormone in the blood stream is different for juncos from these different populations. This is correlated to the amount of exploratory behavior they engage in. The variation in this physiological mechanism is heritable, which leads to variation in behavior between juncos.
L22 Putting pieces together	How did the UCSD population become bolder than the mountain population over the last 60 years?	Previous phenomena from L18 through L21	Natural selection can explain the differences in the boldness of individuals from the two junco populations.
L23 Investigation	Why did some of the juncos stay in San Diego in the first place (and why did the rest migrate back)?		Artificial lighting (from campus) triggered the release of sex hormones in some juncos earlier in the year than would occur naturally. This led those juncos to start their mating calls before flying back to the mountains. This resulted in attracting mates which led to having offspring on the UCSD campus. Juncos that did this ended up repeating this mating pattern and staying on campus year round.
L24 Investigation	Are these different kinds of juncos? How different are they?		There are many physical, behavioral and physiological trait differences between the mountain and UCSD Junco populations. This divergence happened in just 60 years of being separated from one another.

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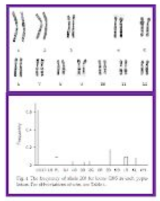
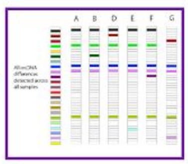
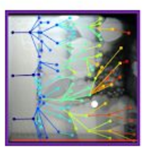
Lesson Routine	Questions	Phenomena / Problems	What we figured out
L25 *Investigation* ↓	What other Juncos do we find in North America?		Different looking populations of Juncos are found in different breeding ranges across N. America. Some breeding ranges overlap, while others are more isolated. Juncos from different populations in overlapping ranges sometimes mate with each other (hybridize).
L26 *Investigation* ↓	Are the UCSD juncos now a separate species from the mountain juncos?		Alleles missing from the gene pools of the mountain vs. UCSD junco populations provide evidence that they aren't interbreeding (or if they are, the babies aren't surviving). We think these juncos should be considered separate species.
L27 *Investigation* ↓	How else can DNA help us figure out how closely related two different populations are?		Some of these populations of juncos are considered separate species. Patterns in haplotypes found in juncos mtDNA helped us determine which ones shared a common ancestor more recently than others.
L28 *Investigation* ↓	Where do new heritable trait variations come from?		Random mutations in the DNA that offspring inherit are rare, but can appear in either asexual and sexually reproducing organisms. Small random mutations can result in the emergence of new traits.
L29 *Putting pieces together* ↘↓↙	How can our mechanisms of evolution explain how all life on Earth has changed over time?		Species go extinct when traits that are well adapted to a changed environment do not exist in the population. When this happens, it can open up opportunities for new species to emerge to take advantage of available resources needed for survival and reproduction that used to be consumed by the now extinct species. We think our model of evolution that we developed can explain how all life on Earth has changed over many millions of years.

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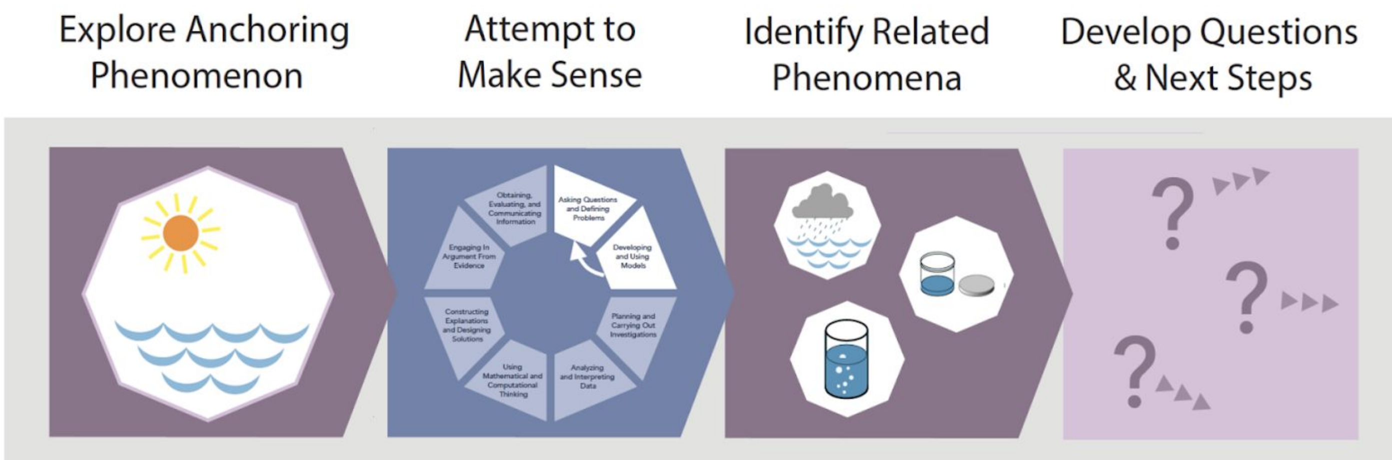
H. How Can Teachers Use Similar Instructional Routines Across Lessons?

If you look at the left hand column of the skeleton you will see reference to a series of routines used with each lesson. Embedded in our curriculum materials are five instructional routines that are used to support three-dimensional learning throughout this unit and can be applied to other units of instruction. These routines are not meant to be interpreted as a step-by-step guide, but rather as dynamic elements used in NGSS Storylines to achieve the goals of three-dimensional learning outlined in *A Framework for K-12 Science Education* and with the Next Generation Science Standards. Here we attempt to summarize and make the design rationale of storylines explicit using each of the five routines. Use the far left column in the Storyline Skeleton to identify where in the unit each routine is used.

Anchoring Phenomenon Routine



There are four main parts of the Anchoring Phenomenon (AP) Routine, which occur at the start of every unit:

Explore 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 occured. 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.

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. Oftentimes, people view this attempt to make sense of the phenomenon as pointless. For example, they may think that we know the students don't understand what's going on, so why take the time for them to try and come up with a reason to explain the phenomenon when it's going to be wrong? The intention of this section is not to come up with the "right" answer. The purpose is to start to stake out the territory of what they don't know yet so that later, we can up come with a plan to figure out those pieces. It's 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 here is very productive! It helps create the sense that we are all not on the same page, and that there is stuff here that needs to be figured out. The role of the teacher in this stage is two-fold: 1. To help students get their thinking down on the page, regardless of if it's right or wrong 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. More

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likely than not, even students who use correct vocabulary to explain what they think is going on cannot really tell you what those words mean in a mechanistic way.

Identify Related Phenomena: The goal of NGSS storylines isn't just to solve a single mystery about one phenomenon; the goal is to build up disciplinary core ideas and cross-cutting concepts that can be applied to a range of events in our world. It's important to frame brainstorming-related phenomenon around the aspects of the phenomena that lead to the target pieces of the disciplinary core ideas. The purpose of having students generate related phenomena is to broaden out the scope of what the class is really interested in figuring out and for students to have a personal connection and investment in the events explored in class. In fact, if students are not able to come up with related phenomena, then that might be a sign the anchoring phenomenon needs to be adjusted because kids won't care or relate to what the class is working on.

Develop Questions and Next Steps: In this section, 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 may take on various forms such as a "Driving Question Board" or a "Notice and Wonder" chart. Similarly, students should be involved in thinking about ways to go about answering one or more of the questions from the class. This early on 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, anything goes! The questions and next steps that are kept on a public class record should be kept alive! Questions and next steps should be revised, revisited, and checked off as the unit progresses.

Here is a tool that can be used for this instructional routine: [Anchoring Phenomena Routine Analysis Tool]

Navigation Routine

There are two main parts of the Navigation Routine, which occur between every lesson in the unit. Think about the idea of navigation. When you are on your way somewhere and actively navigating, you have to constantly address two types of questions. First, where are we now? And 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.

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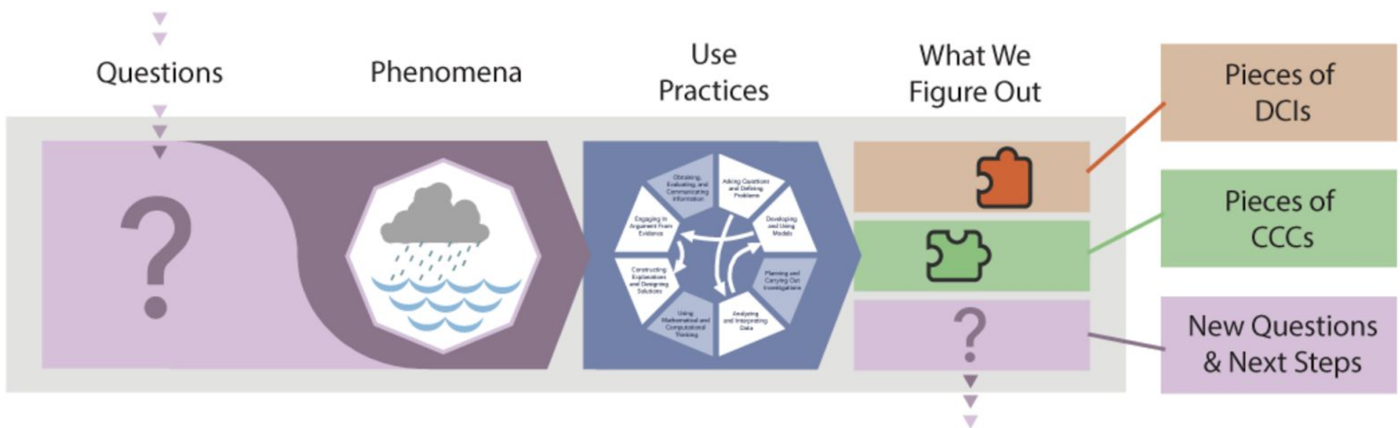
Looking Back: Each lesson begins and ends with reflection or looking back. The class asks, "What brought us to this point?" At the start of each lesson, the learning community needs to look back and remind themselves: Where are we in our mission? What have we accomplished? What's the main thing we need 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 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. And the purpose of reflecting isn't just to recap, it's to prime the pump so the class can think about, "Now knowing where we are, what makes sense to do next?" (Looking Forward).

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 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



Questions regarding phenomena led the class to engage in science practices to make sense of the phenomenon, and then develop the science ideas as part of the explanation. This is the basic structure of three-dimensional learning. We refer to this as the investigation routine.

Questions / Phenomena: Notice there is a yin yang symbol between the question and phenomena segments. This is because the question and phenomena are tightly coupled. There is a column of arrows above the question block because often times 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. You can think of each step in the storyline as a step forward in knowledge-building, starting with a question arising from a phenomenon.

Use Practices: Students use science practices such as designing investigations, analyzing data, modeling, and argumentation to progress in their explanation. The bulk of the class' time and energy is spent in this space - using NGSS practices to make sense of a puzzling phenomenon and question. Kids should be doing the heavy lifting of figuring out.

What We Figure Out: At each step they assemble another piece of the puzzle. It might be a piece of a disciplinary core idea, such as the idea that a vibrating object can make sound. They may also be extending their ideas of

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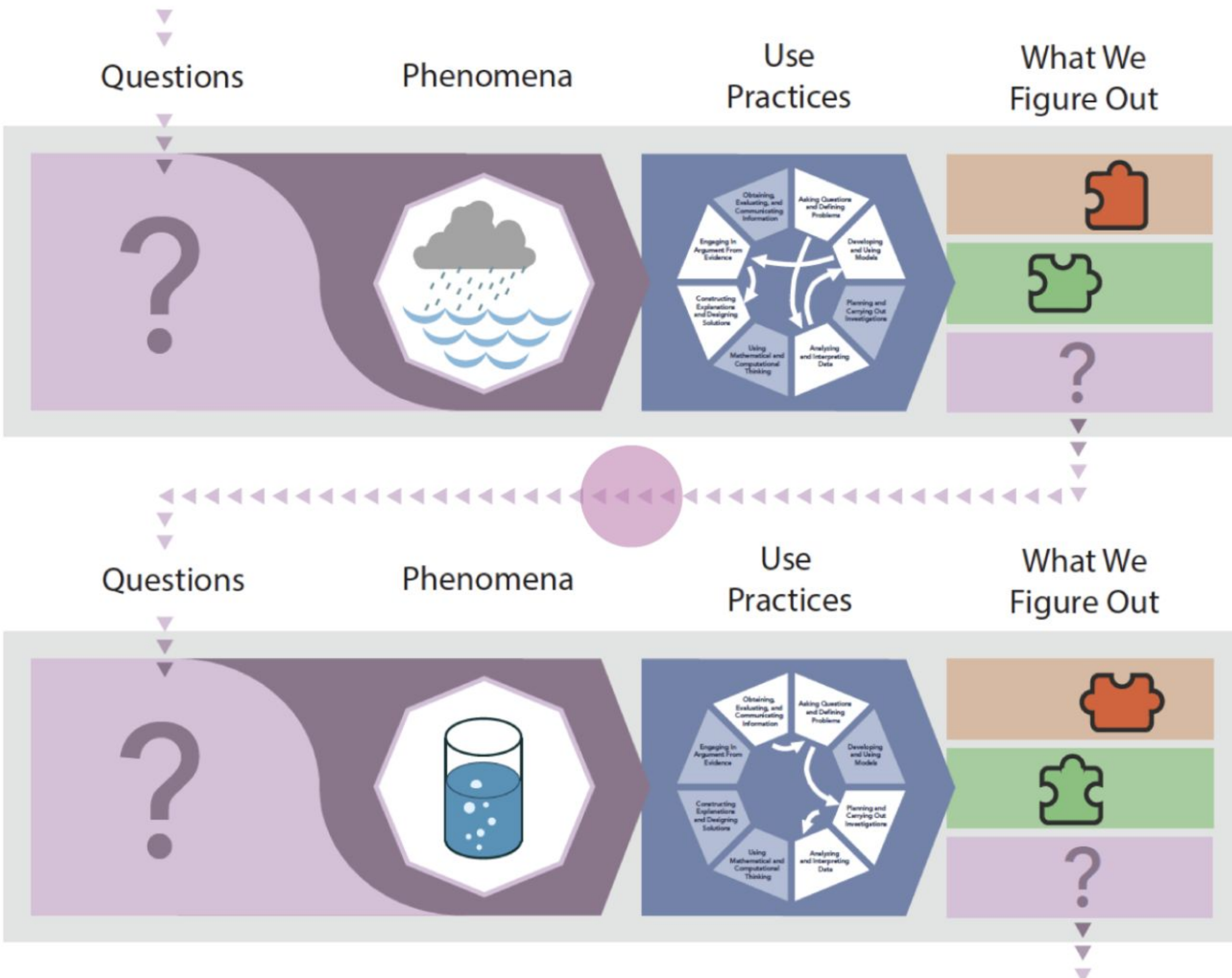
crosscutting concepts such as matter and energy. Notice that students didn't learn about the science ideas first, and then engage in practices to use those science ideas to explain a phenomenon; it was the reverse.

Connected Investigations

Two intertwined 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. In other words, it helps the class bring a new question into focus and set a new trajectory for the next investigation. Both Navigation and Investigation routines coupled together, are in service of supporting two types of coherence: WE figure out the pieces of the science ideas and WE decide our next steps. So together they are really supporting Connected Investigations. Here is a tool that can be used to look for Navigation and Investigation Routines: [Connected Investigations Analysis Tool](#).

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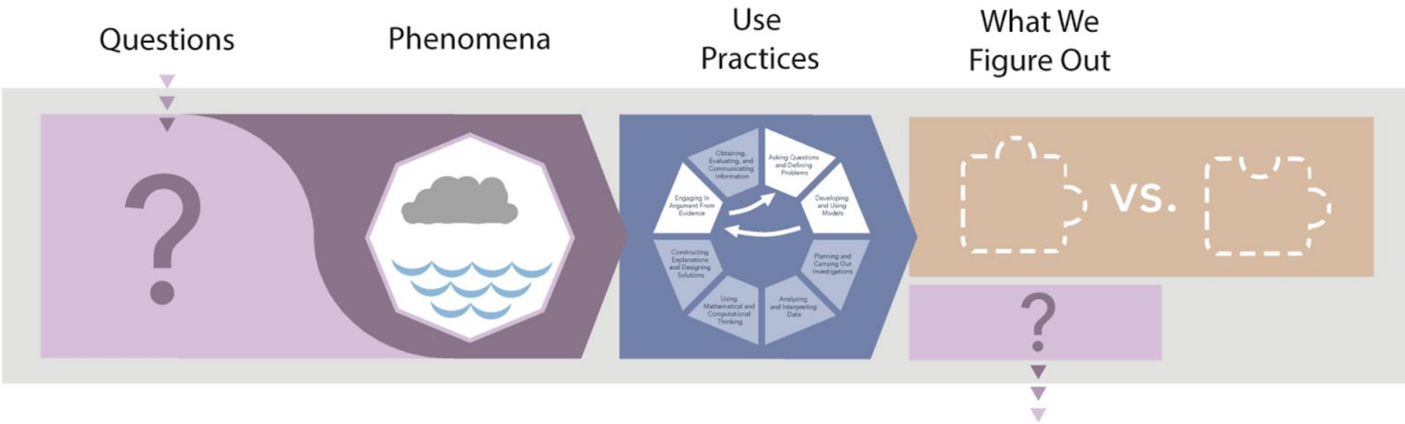
Problematizing Routine



The teacher seeds, cultivates, and capitalizes on an emerging disagreement that reveals a potential problem with their current model to get students to focus on an important question that could extend their model. There are three elements of this routine.

Foreground a new question or phenomena: The teacher helps orient the learning community to a new puzzle for the class to consider that it is intentionally designed to elicit disagreement or competing explanations. The role of the teacher in this piece is to draw attention to and press the class for whether a particular key science idea they had developed could be pushed beyond what they had considered so far. This type of move is really important for NGSS. What makes a science idea a disciplinary core idea is that it can be used to explain a broad range of phenomena. Once we make some progress in explaining phenomena, we need to try to extend or break the model; so we intentionally throw a wrench in the class’ progress.

Argue for competing ideas: In this section, the learning community attempts to really dig into the new puzzle and argue for their predictions or explanations. When students tried to use their model in a new context, they brought some competing ideas to the table. The role of the teacher here is to help the students to go public with their competing ideas and help the class realize they do not have consensus.

Determine a way to resolve this question: Third, students need to figure out what to work on next, and start to think about how to resolve this question. 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.

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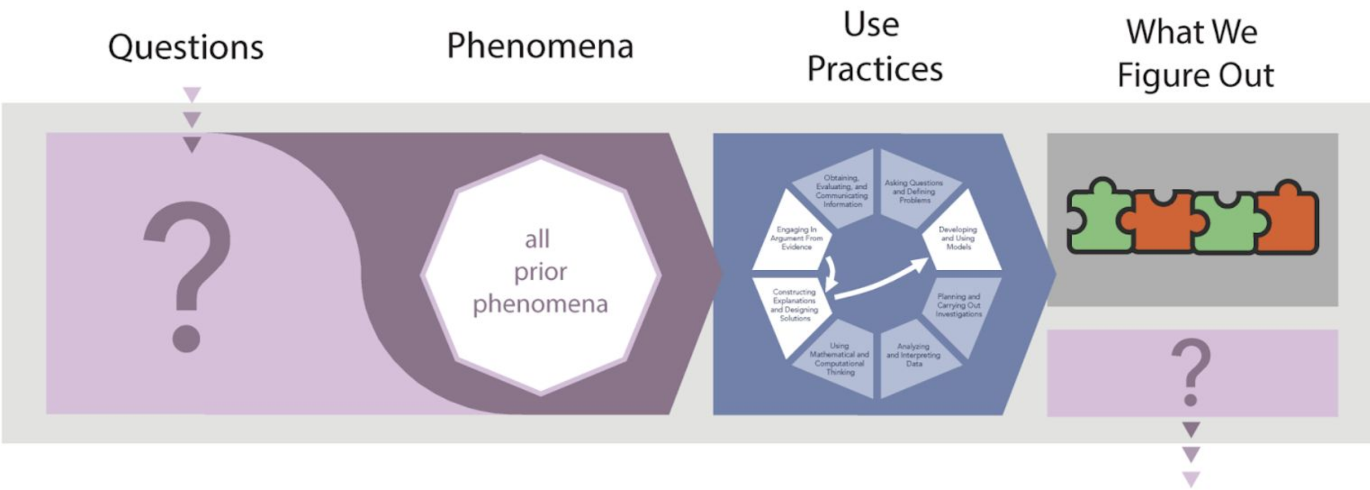
Putting Pieces Together Routine



Students take the pieces of ideas they have developed across multiple lessons and figure out how to they can be connected together to account for the phenomenon they have been working on.

Take Stock: The first element focuses on taking stock of the main punchlines the class has figured out so far. This could take different forms. Students might highlight the important discoveries they made in their science notebooks. They might fill out a summary chart of what the class figured out with regard to the question that framed each lesson. 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 step is to get all the pieces of the puzzle out on the table.

Put Pieces Together: The second element involves coming to a consensus on how to put these ideas together to explain a phenomenon or to design a solution. During this process, the class develops a physical representation of the ideas as we are putting them together; such as a diagrammatic model, a table showing commonalities across a series of cases, or a written explanation.

Apply This to Another Phenomenon (Optional): Sometimes the class is ready to go further, and we see a third element of this routine emerge. After the class confidently comes to a consensus on a public representation of how the pieces fit together, they may attempt to generalize the ideas they just put together by applying them to explain new phenomena or solve new problems.

Here is a tool that can be used to look for the Problematizing and Putting Pieces Together Routines: [Problematizing and Putting Pieces Together Routines Analysis Tool](#).

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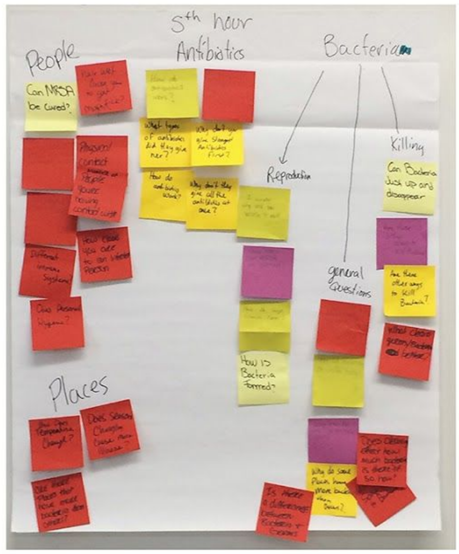
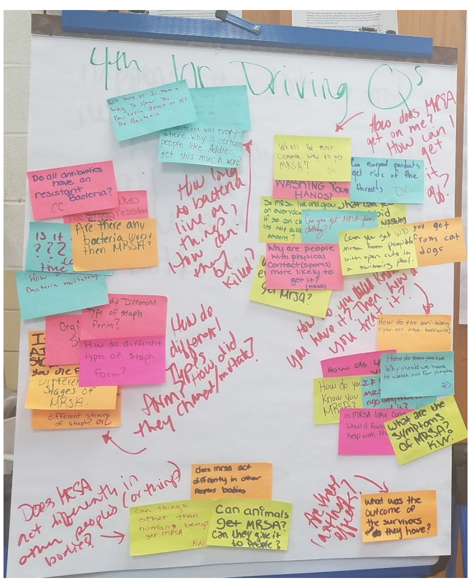
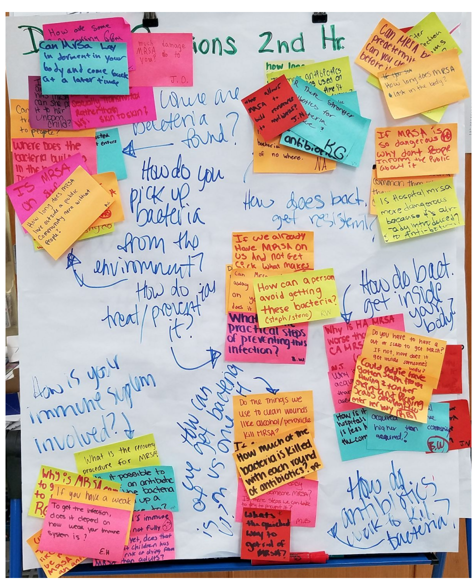
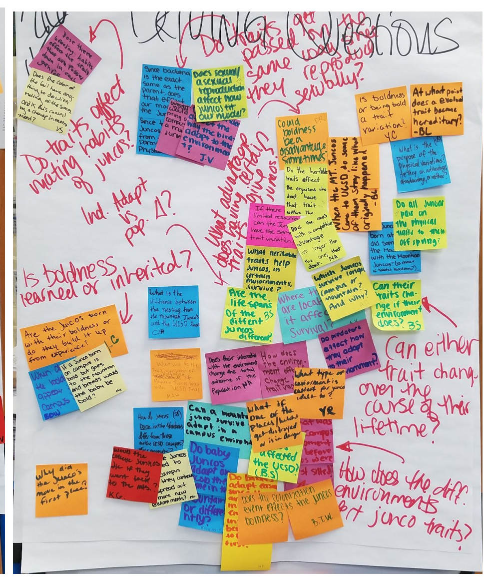
Driving Question Board

Below are examples of the questions that students posted to The Driving Question Board (DQB) at the end of first lesson of this storyline. The questions are from six classes of ninth-grade students, from two different teachers classrooms. The Driving Question Board is an essential tool for developing a sense of joint mission in your classroom learning community for this storyline.









Keeping multiple Driving Question Boards active for multiple classes when you have limited wall space can be logistically difficult. One possible solution is shown to the right.

You will help students develop a new Driving Question Board at the start of the second bend of this unit, after the introduction of the juncos case.

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I. What Assessment Resources Are There?

The evolution unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self-assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. Please see the HS Evolution Assessment Folder for all the assessment resources. There is also a table that outlines where each type of assessment can be found in the unit.

J. How Can Teachers Support Different Types of Discussions?

Ideas for this resource are developed from the Next Generation Science Exemplar program and from research on fostering productive academic talk in science. Productive talk is the glue that connects practices to one another, and practices to DCIs and crosscutting concepts. Productive talk also helps the class make sense of what they figure out.

There are four basic types of discussion that can facilitate science learning in ways that are consistent with the vision of *A Framework for K-12 Science Education* and with the Next Generation Science Standards:

Generating and Prioritizing Questions Discussion
Initial Ideas Discussion
Building Understandings Discussion
Consensus Building Discussion

These different discussions serve different purposes, and they are useful in different phases of a lesson or unit centered around an anchoring phenomenon or engineering design challenge. We have indicated which phases of a lesson or unit when different types of discussion might be valuable, but any type of discussion could be useful depending on what students are thinking and wondering about at the time. When planning for a classroom discussion, it is also important to think about how all students can contribute ideas and to create opportunities for individual and small group "think time."

Generating and Prioritizing Question Discussions

Purposes

- To identify questions students need to answer, in order to solve an engineering design challenge or to develop a complete explanatory model of a science phenomenon
- To identify questions that students need to answer, to refine their understanding of a problem
- To identify questions that students want to investigate, in order to develop a piece of understanding related to a phenomenon
- To help motivate the next row(s) in an NGSS storyline
- To support students in developing a grasp of the practice of asking questions and defining problems
- To identify questions that come from students' personal experience and interests that relate to the challenge or phenomenon

Some Unit Phases When Useful
At the beginning of a unit
At the conclusion of a "bend" in the storyline

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Some Lesson Phases When Useful
"*What questions do we still have?"*
"Where should we go next?"

Steps in a Possible Discussion Routine
1. Elicit Questions
2. Clarify Meanings of Questions
3. Discuss Significance of Questions
4. Prioritize the Questions

Potential Talk Moves for This Discussion

For Eliciting Initial Questions
- What questions do we need to answer to solve the design challenge just presented?
- If we want to explain this phenomenon, what questions will we need to be able to answer?
- What questions do we now have after being introduced to this phenomenon?
- What questions do we need to ask the client/partner to refine our understanding of the problem they are trying to solve?
- What questions should we try and answer with this investigation? How will answering those questions help us figure something out about the phenomenon?
- What questions should we try and answer with this test of our design solution? How will answering those questions help us figure out something we need to know to solve the design challenge?

For Prioritizing Questions
- Which of our questions are similar? What makes them similar?
- Which questions should we answer first? Why do those questions come first?
- 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, ones that might help us make progress on a larger set of related questions?

Making Participation Equitable
In eliciting questions, the goal is to get as many ideas on the table as possible, so group work is a better option. Consider asking students to "write and pass" a sheet of paper around their group until they have at least 10 things. That way, all students get a chance to contribute, see others' ideas, and add their thinking in a low stakes way.

Then, use groups to prioritize questions for the class investigations. Have groups pass their written list 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.

Initial Ideas Discussion

Purposes
- To provide a supportive opportunity for students to make some sense of what may be not yet fully formed ideas (either their own or those of others)
- To support students in making tentative connections between questions being asked and the participants' experience and everyday ideas about observing a phenomenon

Some Unit Phases When Useful
At the beginning of a unit
At the beginning of a new "bend" in a storyline

Some Lesson Phases When Useful
"What are some ideas about how we can answer what we're wondering about?"

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Steps in A Possible Discussion Routine

1. Provide a way for all students to surface their ideas (think-pair-share is one strategy)
2. Give people a chance to clarify one another's ideas and to ask about why people think their ideas are good ones
3. Ask a student to summarize the initial ideas that the class has
4. Ask students how they might test or further explore their ideas

Potential Talk Moves for this Discussion

When eliciting initial ideas:

- What are your ideas about how to explain this phenomenon?
- What's your "first draft" thinking about how to solve this design challenge?
- Let's see what we think about this phenomenon, using our past experiences and what we've learned in class this year as a guide.
- What experiences do you have that might help you with this phenomenon?

When clarifying ideas and pressing for reasoning:

- 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 "______"?
- Can anyone add onto this idea?
- Who has a different way of thinking about this topic?
- Can you think of an instance when this was not the case?

When asking a student to summarize initial ideas:

- Who can summarize some of the ideas we've heard today?
- Is this a complete summary? Can someone add what's missing?
- Does the summary capture our ideas accurately?

When asking students for how to investigate their initial ideas:

- What are some ways we could test our initial thinking?
- What ideas are we unsure about, that we need to know more before we can be confident in them?

Making Participation Equitable

Think about what kinds of supports your students might need to be able to *ask each other* these kinds of clarifying and summarizing 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 partner practice as a scientist and supporting them in their thinking, so you're going to ask questions, encourage them; 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 partner."

Tip: Have sentence starters ready for students so they know what to ask to push their partner further, but *also* have sentence starters to slow down the fast explainers, such as "Wait - you said that really fast. Can you say that again?"

Building Understandings Discussion

Purposes

- To help students make their reasoning with evidence public so that other students can connect with it, critique it, and build on it if possible
- To provide the teacher and students with an opportunity to clarify which understandings emphasized in the storyline have been developed and which need further development

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<u>Some Unit Phases When Useful</u>
After a series of lessons where a piece of understanding should have been built toward the end of a "bend" in the storyline

<u>Some Lesson Phases When Useful</u>
- *"What did we figure out last time? What did we wonder about?"*
- *"What have we figured out today? What questions do we still have?"*

<u>Steps in A Possible Discussion Routine</u>
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/solution, suggest additions to it, and critique the model/solution
3. Invite a second student or group to share their model/solution, and then invite response and critique
4. Ask students about how the models/solutions compare, in terms of similarities and differences
5. Invite the class to consider what might need to be revised in models/solutions, based on the models seen and the evidence so far

<u>Potential Talk Moves for this Discussion</u>

When inviting a group to share:
- What are some of the key components of your model/solution?
- 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?
- Did you consider other models/solutions? If so, what were they?
- For second group and after: How is your model/solution different from or similar to ones presented earlier?

When inviting others to critique a model/solution:
- What questions do you have for this group about their model/solution?
- Can you clarify __________ aspect of your model/solution?
- So let me see if I understand this aspect of your model/solution here. Are you saying...?
- What do the rest of you think of that idea?
- Is there anything you can add to this model/solution?
- How well does this model fit the evidence we've gathered so far?
- How well does this solution meet the criteria we identified for the solution?
- What could the group do to improve the model/solution?

When inviting students to compare models/solutions and consider revisions:
- How does group A's solution connect to group B's?
- How does these models/solutions help us make sense of and contribute to our question at hand?
- What might a model/solution look like that puts the things we think best reflects <u>all</u> the evidence we have so far?
- Is there any evidence that we have that none of our models/solutions can account for?

<u>Making Participation Equitable</u>
Consider lower-stakes ways for students to have these discussions, such as in a gallery walk where one person stays by the model to invite critique with the questions above and the 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."You can also encourage students to take a "coaching" stance here; their role is to ask questions that support others' ideas, and encourage students to speak up when something needs to be repeated.

Consensus Building Discussion

<u>Purposes</u>

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- To press toward a common (class-level) explanation or model, resolving (if possible) disagreements, different perspectives, or partial understandings
- To support public revision of earlier ideas, as new ideas are shared and as they learn information that makes visible the limitations of previous understandings held by individuals or even the class as a whole

Some Unit Phases When Useful
After a series of lessons where multiple pieces of understanding should have been built
At the end of a "bend" in the storyline

Some Lesson Phases When Useful
"What have we figured out today? What questions do we still have?"

Steps in a Possible Discussion Routine
1. Ask students to take stock of where the class has been and what they've figured out, offering conjectures or pieces of a model, explanation, or solution.
2. Ask students to offer proposals for a synthetic model, explanation, or solution
3. Ask students to support or challenge proposals, and say what evidence is the basis for their support or critique
4. Ask students to propose a modification to the model based on input from the class

Potential Talk Moves for this Discussion

During stock-taking:
- What are some things we can say at this point about our anchoring phenomenon that are supported by evidence?
- Could you clarify the link you are making between your explanation and the evidence?
- Could someone restate our question (or our charge)? What are we building consensus about?

When inviting proposals for a synthetic model/explanation/solution:
- How are these explanations similar? How are they different?
- Both groups seem to be using the same term but in a different way, could someone explain the difference?
- Could someone restate our question (or our charge)? What are we building consensus about?

When inviting support or critique:
- Who feels like their idea is not quite represented here?
- Would anyone have put this point a different way?
- What ideas are we in agreement about?
- Both groups seem to be using different language to explain the same idea, is that what you are hearing?
- Are there still areas of confusion or discontent?
- Are there still places where we disagree? Can we clarify these?

When inviting modifications to models/explanations/solutions:
- How could we modify what we have so that we account for the evidence we agree is important to consider?
- What modifications might you make to clarify any confusion or address the discontent the group feels?
- Is there more evidence or clarification needed before we can come to agreement? What is that?

Making Participation Equitable
Many students are not comfortable being the "only one" who voices a disagreement, a discontent, or a potentially incorrect idea, so ask students to think-pair-share and to carefully listen to their partners' ideas. Then ask students to think about what they heard their partners saying, and ask the room if *their partners'* ideas are represented in the class discussion. This supports all students to share, to listen, to be heard, and to be represented.

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K. How Can Teachers Support the Development of Scientific Vocabulary?

Some instructional approaches emphasize the role of introducing key vocabulary before learning about the concepts they are connected to in a lesson.

That is not an approach we support through our storylines. While we agree that developing scientific terminology is one important goal for students, it should not undermine the heavy lift we want to engage students in. In each lesson we want students engaging in practices around a question that they feel a genuine need/drive to figure out. Front-loading vocabulary gives away the punchline for that lesson.

Once ALL students have developed a conceptual understanding of an idea in a lesson, introducing a relevant scientific term as shorthand way to reference that idea makes complete sense. It is simply a matter of timing.

Here is an example. In Lesson 5, students will notice the graph of the vibrations produced by object exhibits two interesting characteristics. A few rounds of describing patterns (individually, with a partner, and then in a whole group) will lead students to start talking about two features of these patterns that can be compared and measured. One can be described in terms of the distance from the y-value of a high point on the graph. The other can be described in terms of how often that pattern repeats. It is at this point, after the class has worked with these ideas for a bit and wrestled with what words best describe each feature, that the teacher can point out that it seems a bit cumbersome to keep referring to these features to describe the graphs in such a way, and that there are two terms that other use to refer to these features. One is amplitude and one frequency. At this point, it makes sense to consolidate students ideas by showing how these two terms correspond to the patterns they observed. From this point on, using these terms to represent these features of such graph makes total sense.

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 lessons. We want to give them a rich opportunity and experience to wrestle with these developing these important science ideas before introducing vocabulary to represent an abbreviated description of those ideas.

Key scientific terminology to connect in "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.

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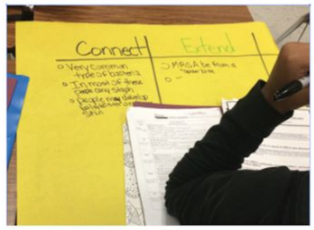
L. How Can Teachers Support Differentiated Instruction?

Differentiation strategies are built into individual lessons in the Teacher Supports section of the Learning Plan. An example strategy from lesson 2 is show below

5. (10 min) After modeling, place students into 5 groups, C and give each group one of the documents listed in the Materials section above along with a sheet of chart paper. Instruct students to use the thinking routine you modeled to engage with these materials. As they do, students should record their thinking on the chart paper. Remind students that once they have completed their work in their teams they will be asked to share out their findings with the whole group.



6. (15 min) When students are ready to present their findings, put these five questions up on the board or on separate pieces of chart paper. Tell students before they share out that as groups share, we will try to see if any of their articles can shed light on one of these questions. D

1. **Who gets MRSA?**
2. **Is there only one variation/strain of staph (is there only the MRSA variation)?**
3. **What is the history of resistance to different strains of bacteria?**
4. **How many cases like Addie’s were there in the past?**
5. **What do community-associated MRSA and hospital-acquired MRSA mean?**

Use the following prompts to guide their sharing in a Building Understandings Discussion.

Suggested Prompts:
→ What key takeaways helped you answer any of these questions?
→ What did you learn that was new or unexpected related to these questions?

Listen for *student responses* such as:

→ *Who gets MRSA?*

Differentiation Strategies and Alternate Activities

C Use your discretion as to the number of groups and the number of students in each group. You may want to do a shared reading of one of the articles while modeling the thinking routine for students. If you choose this option, you can have multiple groups read the same article, because there will only be four articles remaining.

The articles provided for students are written at various difficulty levels. In order to meet the needs of your students, be sure to assign students to groups strategically, and likewise assign articles that students will be able to access.

It may be helpful to work directly with the group to which you assign the article, “A diversity of Antibiotic-resistant *Staphylococcus* spp. in a Public Transportation System.” Students should only work with the abstract of this study, but it is important to help them make sense of the highly scientific language in that abstract.

The image below shows another alternate form of this activity. It shows students

Every lesson provides opportunities for students to articulate new questions and ideas for investigations that the class should pursue at the end of the lesson. Though the Teacher Guides for subsequent lessons provide ideas for how to investigate the questions that are most commonly raised by students, using novel ideas that students raise for ways to investigate these questions increases students’ sense of agency, as well as providing opportunities to extend investigation design to the level that students can articulate.

At the end of most lessons, the teacher guide prompts the teacher to have students keep track of the big ideas that they figured out in their Incremental Modeling Tracker (IMT). This resource serves as useful “single stop” location for students to look to review the big ideas they will use as they develop and revise their models. Teacher Guidance for the Incremental Modeling Tracker can be found on 31 page of the front matter.

Encourage students to return to referencing either of these resources during summative assessments. Or for students who you want to challenge others, encourage them to do these assessment first without this reference.

Lastly, consider using unanswered questions from the Driving Question Board as opportunities for students to pursue additional research about any of the topics they selected, after the storyline is complete.

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M. How Can Teachers Use the Incremental Modeling Tracker?

The Incremental Modeling Tracker (IMT) is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating Addie’s case, and to help them figure out how to prioritize and use those discoveries to develop a model to explain Addie’s case. Students will refer back to the IMT regularly to help them prioritize ideas and revise or build on their models for what’s going on with Addie. Furthermore, students will use the IMT as a way to think with others about what is important in their models.

It is important to note that this tool was designed to be a dynamic resources that students can use to progressively make sense of their ideas. We suggest that teachers use this tool to support progressive sense-making throughout the unit, and avoid using this tool as a simple note-taking activity. In the teacher guidance, suggestions are given for supporting students in using the IMT in a dynamic way to identify discoveries and use those discoveries to continually revisit, revise, and prioritize ideas in our models. In order to avoid model fatigue, teachers should not have students use the IMT every day in the same way, but rather, use it to further the sense-making when applicable. Students will use their ideas to support their work in figuring out important discoveries in Addie’s case and ways to apply these ideas to their models.

The IMT Teacher Guidance with example student responses can be found in the Lesson 1 folder. In the example IMT, each of the rows and columns has been completed with POSSIBLE student ideas. This IMT serves as teacher guidance for what students may say at various points throughout the unit. Some students may say more and others may say less. It is important that what the students write in the IMT reflects their own thinking at that particular moment in time. In this way, the IMT can be used to formatively assess individual student progress throughout the unit. Because the IMT is meant to be a thinking tool for kids, we strongly suggest it not be collected for a summative “grade” other than for completion. This is to avoid undermining the freedom for students to put their current understanding and questions about their developing models without concern of being “right or wrong.”

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