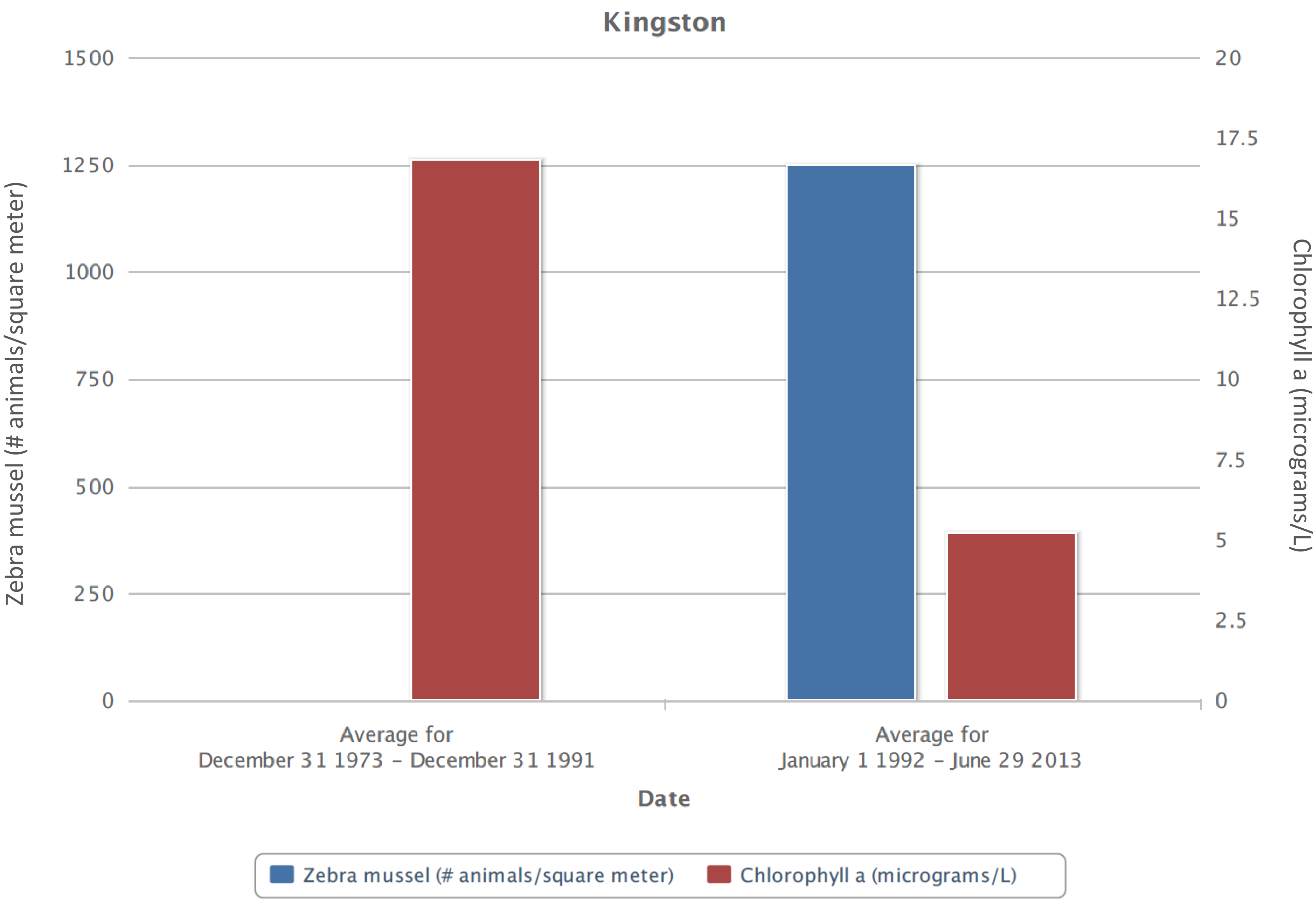
Kingston
1500
1250
1000
750
500
250
0
20
17.5
15
12.5
10
7.5
5
2.5
0
Zebra mussel (# animals/square meter)
Chlorophyll a (micrograms/L)
Average for
December 31 1973 – December 31 1991
Average for
January 1 1992 – June 29 2013
Date
Zebra mussel (# animals/square meter)
Chlorophyll a (micrograms/L)

Developing a Scientific Explanation Tool (DSET)

What is the question?

Components of a scientific explanation

Claim	Evidence	Scientific Reasoning
What is the answer to your question?	***What are the raw data that support a particular claim?***	***What is the scientific principle(s) that forms a logical connection/relationship between the claim and evidence?***

Scientific Explanation = Claim + Evidence + Scientific Reasoning

My claim is <u>(fill in with above claim)</u> because <u>(evidence and scientific reasoning)</u>

Developing a Scientific Explanation Tool (DSET)

What is the question? How will the arrival of zebra mussels in the Hudson River affect phytoplankton populations?

Components of a scientific explanation

Claim ***What is the answer to your question?***	**Evidence** ***What are the raw data that support a particular claim?***	**Scientific Reasoning** ***What is the scientific principle(s) that forms a logical connection/relationship between the claim and evidence?***
The zebra mussels significantly reduced the concentrations of phytoplankton in the Hudson River.	Before Jan 1, 1992, the concentration of chlorophyll a in the Hudson River was 17.5 micrograms/L. There were no zebra mussels. Between Jan 1, 1992 and June 29, 2013, there were 1250 zebra mussels per square meter and chlorophyll a dropped to 5 micrograms/L.	We know from our study of food webs that zebra mussels are filter feeders and consume small planktonic organisms such as phytoplankton. While there could be other reasons, the fact that chlorophyll a dropped dramatically once the zebra mussels arrived is probably due to high concentrations of zebra mussels eating the phytoplankton.

Scientific Explanation = Claim + Evidence + Scientific Reasoning

My claim is <u>(fill in with above claim)</u> because <u>(evidence and scientific reasoning)</u>

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Ecosystems: Interactions, Energy, and Dynamics

INTERDEPENDENT RELATIONSHIPS IN ECOSYSTEMS

Animals depend on their surroundings to get what they need, including food, water, shelter, and a favorable temperature. Animals depend on plants or other animals for food. Plants depend on air, water, minerals (in the soil), and light to grow. Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight.

Plants are considered “producers” because they use photosynthesis to produce their own food. Animals are considered consumers “consumers” because the food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants and animals) and therefore are “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil for plants to use.

Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete for limited resources, access to which consequently constrains their growth and reproduction.

Organisms can survive only in environments in which their needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.

CYCLES OF MATTER AND ENERGY TRANSFER IN ECOSYSTEMS

Organisms obtain the materials they need to grow and survive from the environment. Many of these materials come from organisms and are used again by other organisms.

Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, water, and minerals from the environment and release waste matter (gas, liquid, or solid) back into the environment.

Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

Three Dimensions of the *Framework for K-12 Science Education* Being Used to Develop the *Next Generation Science Standards* (NGSS)

Scientific and Engineering Practices

Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.

Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world.

Both scientists and engineers also ask questions to clarify the ideas of others.

Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.

Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

Constructing Explanations and Designing Solutions

The products of science are explanations and the products of engineering are solutions.

The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories.

The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

Engaging in Argument from Evidence

Argumentation is the process by which explanations and solutions are reached.

In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits.

Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to identify strengths and weaknesses of claims.

Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.

Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. Statistical methods are frequently used to identify significant patterns and establish correlational relationships.

Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to acquire information that is used to evaluate the merit and validity of claims, methods, and designs.

Disciplinary Core Ideas in Physical Science	Disciplinary Core Ideas in Life Science	Disciplinary Core Ideas in Earth and Space Science	Disciplinary Core Ideas in Engineering, Technology, and the Application of Science
PS1: Matter and Its Interactions PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS1.C: Nuclear Processes **PS2: Motion and Stability: Forces and Interactions** PS2.A: Forces and Motion PS2.B: Types of Interactions PS2.C: Stability and Instability in Physical Systems **PS3: Energy** PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces PS3.D: Energy in Chemical Processes and Everyday Life **PS4: Waves and Their Applications in Technologies for Information Transfer** PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation	**LS1: From Molecules to Organisms: Structures and Processes** LS1.A: Structure and Function LS1.B: Growth and Development of Organisms LS1.C: Organization for Matter and Energy Flow in Organisms LS1.D: Information Processing **LS2: Ecosystems: Interactions, Energy, and Dynamics** LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS2.D: Social Interactions and Group Behavior **LS3: Heredity: Inheritance and Variation of Traits** LS3.A: Inheritance of Traits LS3.B: Variation of Traits **LS4: Biological Evolution: Unity and Diversity** LS4.A: Evidence of Common Ancestry and Diversity LS4.B: Natural Selection LS4.C: Adaptation LS4.D: Biodiversity and Humans	**ESS1: Earth's Place in the Universe** ESS1.A: The Universe and Its Stars ESS1.B: Earth and the Solar System ESS1.C: The History of Planet Earth **ESS2: Earth's Systems** ESS2.A: Earth Materials and Systems ESS2.B: Plate Tectonics and Large-Scale System Interactions ESS2.C: The Roles of Water in Earth's Surface Processes ESS2.D: Weather and Climate ESS2.E: Biogeology **ESS3: Earth and Human Activity** ESS3.A: Natural Resources ESS3.B: Natural Hazards ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change	**ETS1: Engineering Design** ETS1.A: Defining and Delimiting an Engineering Problem ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution **ETS2: Links Among Engineering, Technology, Science, and Society** ETS2.A: Interdependence of Science, Engineering, and Technology ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World

Crosscutting Concepts		
Patterns Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them. **Cause and Effect: Mechanism and Explanation** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	**Scale, Proportion, and Quantity** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance. **Systems and System Models** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	**Energy and Matter: Flows, Cycles, and Conservation** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations. **Structure and Function** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions. **Stability and Change** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

MSLS2 Ecosystems: Interactions, Energy, and Dynamics
Common Core State Standards Connections

ELA/Literacy -

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. (MS-LS2-1), (MS-LS2-2),(MS-LS2-4)
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-LS2-1)
RST.6-8.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (MS-LS2-5)
RI.8.8	Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound, and the evidence is relevant and sufficient to support the claims. (MS-LS2-4), (MS-LS2-5)
WHST.6-8.1	Write arguments to support claims with clear reasons and relevant evidence. (MS-LS2-4)
WHST.6-8.2	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS2-2)
WHST.6-8.9	Draw evidence from literary or informational texts to support analysis, reflection, and research. (MS-LS2-2), (MS-LS2-4)
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly. (MS-LS2-2)
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (MS-LS2-2)
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-LS2-3)

Mathematics -

MP.4	Model with mathematics. (MS-LS2-5)
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-LS2-5)
6.EE.C.9	Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables and relate these to the equation. (MS-LS2-3)
6.SP.B.5	Summarize numerical data sets in relation to their context. (MS-LS2-2)

Teacher Scenario A: Mr. Coles

Background

Mr. Coles teaches middle school science at the same school as Ms. Rivera. The district has developed a K-12 scope and sequence, a pacing guide, and has recommended a textbook for teachers to use to plan for instruction. The school is focused on using best practices in teaching that support improved learning and achievement for all students. Since the school is also asking teachers to use data to inform instruction, the science department has agreed to give common assessments – end-of-unit chapter tests that all students in the same course take no matter which teacher they have – so that teachers can learn from the data.

Mr. Coles attended a summer professional development institute along with other teachers from his school. The teachers are working together through their school-based professional learning community to implement the ideas and strategies learned during the institute. Mr. Coles and Ms. Rivera attended different institutes and are part of different working groups.

Lesson 1

On the first day of the new chapter on Interdependent Relationships in Ecosystems, Mr. Coles starts the class as he does every new topic: with a question posted on the SmartBoard linked to the district's state test. After a quick review of students' written responses and the correct answer, students are asked to take out the key vocabulary terms that they had defined as part of their homework to prepare for their new chapter. Students had defined the following Tier 3 vocabulary terms: *ecosystems, communities, populations, biotic,* and *abiotic*. He reviews the definitions with students and writes the terms on the Word Wall that will remain there throughout the chapter. Mr. Coles introduces the chapter by giving a short PowerPoint presentation on biotic and abiotic factors and how they can affect populations within ecosystems, while students fill in their guided notes, a strategy they used in a previous chapter. After the presentation Mr. Coles does a read-aloud from the textbook on biotic and abiotic factors. As students read, Mr. Coles has them stop at the end of each paragraph and paraphrase what they read on sticky notes. Then he has them work in pairs to take turns verbally summarizing the paragraphs using their sticky notes as a reference. At the end of the class, he has students write down two biotic and two abiotic factors using a nearby park as an example. For homework, students are assigned four "Connect Questions" from the chapter in their textbook that they covered in class.

Lesson 2

After reviewing homework, Mr. Coles shows students samples of lichen he had collected on the school grounds. He explains that lichen is an example of *symbiosis*, where two organisms live in close association with each other. He then does a mini-lesson on *symbiosis* and explains the difference between *mutualism*, *commensalism* and *parasitism*. Students copy the four definitions into their notebooks and the terms are added to the Word Wall. Mr. Coles shows students a brief video called *Symbiosis: Mutualism, Commensalism, and Parasitism* by Mark Drollinger. After the video, students are given questions to discuss with their partners: What is the difference between Mutualism and Commensalism? How does Parasitism affect the parasite and how does it affect the host? Then Mr. Coles passes out a graphic organizer with three columns for the three types of symbiotic relationships. He models filling out the first column (mutualism) using the example of the lichen he has brought in. For the second column (commensalism) he plays a short video of a leopard shark swimming with remora on its back. He tells students that the shark is not harmed by remora, but that remora get a "free ride," making this an example of commensalism. He has students to complete the second column with a partner. For the third column (parasitism), he plays the HHMI Biointeractive video *Malaria, Human Host,* pausing the video several times to review the main ideas with students and allowing them to record information in their graphic organizer. After the students have completed their graphic organizers Mr. Coles discusses the homework assignment. The assignment is a five paragraph explanatory essay on symbiosis describing the three types of relationships with real world examples. Students receive a checklist and a rubric, and are allowed to use the remainder of the class time to start working on their essays that will be due in two class periods.

Lesson 3
Mr. Coles opens the third lesson with a "Do Now" with two questions from the state test. After a short discussion and review of the correct answers, he passes out a news article titled "When Lions Abound, Hyenas pick a new menu" which describes a real-world example of competition between lions and hyenas. He reads the article out loud with students and has them annotate, paraphrase, and summarize in the margins. He gives them two follow up questions: 1) According to the author why did the competition between lions and hyenas increase between 2005 and 2008?, and 2) Explain what the author means by his concluding sentence: "Hyenas' magnificent jaws offered them another option, giving them plenty of reason to laugh at those pushy lions." Students discuss their answers in pairs and then have a class discussion led by Mr. Coles. In the discussion they collectively come up with a definition of *competition* which is added to the Word Wall. As an exit ticket, Mr. Coles has the students compare and contrast symbiosis and competition.

Lesson 4
After collecting the essays assigned in Lesson 2, Mr. Coles begins the class with a "Do Now" in which students explain "predator-prey", and list of three examples of predator-prey relationships in the wild. Students share their responses with the class. Mr. Coles has prepared three stations on predator-prey interactions which the students rotate through during the lesson. One station had vocabulary terms that students copy in their notebooks and use in a sentence. A second station has various photos with captions showing examples of predator-prey interactions that Mr. Coles got from nature magazines. Students are asked to identify predator and prey in each photo and write a short description of the interaction. A third station is a small group lesson taught by Mr. Coles, in which he explains the idea that populations grow and change over time and that predation is one of the main forces influencing population size. He shows students graphs of predator and prey populations and explains how they can use the graphs to answer questions about both populations such as " What happens to the algae population as the number of daphnia increases?" While he is explaining, the students are filling in the guided notes worksheet and are encouraged to ask questions. After students complete all the stations and are back in their seats, Mr. Coles added *predator-prey* to the Word Wall. Next he projects an image of a snowshoe hare and bobcat and asked the students to identify which is the predator and which is the prey. He asks the students to work in pairs and use large sheets of chart paper to brainstorm and list factors that affect the bobcat and snowshoe hare populations. When they were done, Mr. Coles has the partner groups pair up to briefly compare their posters and exchange ideas. At the end of the class Mr. Coles assigns homework: worksheets with population data for deer and wolves on an island for students to graph and answer follow up questions.

Lesson 5
Mr. Coles reserves time in the school's computer lab to do a virtual predator-prey modeling lab about Canadian lynx and snowshoe hare that he found on eduweb.com. Before starting the lab, Mr. Coles reviews the homework assignment and answers students' questions. He reviews some of the concepts from the previous class and explains the virtual lab. He also brings their attention to a prominently displayed poster detailing the steps of the scientific method and directs them to follow these steps during the lab. Then Mr. Coles explains the lab in detail: what parameters students will follow, and what data will be obtained and analyzed during the lab. Students work in pairs to develop a hypothesis for

their lab and identify the variables in the simulation. Students then follow the written procedure to complete the lab which has them manipulate variables such as the number of hares that each lynx must catch in order to survive and reproduce. They also produce graphs that serve as their results. For homework students were asked to complete the analysis and conclusion sections of their lab reports. All work is due in two days.

Lesson 6
As part of the preparation for the upcoming test, Mr. Coles starts the sixth day by taking down the Word Wall temporarily and giving a clicker-quiz on the vocabulary words covered thus far in the chapter. He asks students who get the correct answers to explain their answers to the rest of the class. After the quiz, Mr. Coles projects a picture of a human surrounded by different organisms (tomato, bacteria, malaria protozoan, cow, grizzly bear, and another human). Students identify the types of relationships humans have with each of the other organisms. Then Mr. Coles divides the class into two groups; each group receives a different reading. One group gets an article on the negative impact of humans on animal populations, titled "Human Impact on Animal Wildlife & Their Habitat," and the second group receives an article on the positive impact of humans on animal populations, titled "12 Innovative Ways Technology is Saving Endangered Species." Mr. Coles prepares his students for an "accountable talk" discussion where they debate the question "Humans: predatory parasites or mutualistic helpers?" Students are expected to use evidence from their readings, data collected during the lab, and science concepts covered in the class to support their reasoning. For their exit tickets students receive two sticky notes: one blue and one yellow. On the blue note students write their "Gots" (what they learned/understood), and on the yellow notes their "Needs" (questions, concerns, concepts they are still confused about). As students leave the classroom they post the notes on two sheets of chart paper hanging by the door. Mr. Coles reminds students that their lab reports are due the next day and that they should come prepared with questions regarding the approaching unit test.

Lesson 7
Mr. Coles begins class by collecting the students' lab reports. He reminds them that they will spend the whole period reviewing for the chapter test (the grade-level common assessment for the unit), which will be given during the next class. During the first half of the period, Mr. Coles has students work on group projects. Each group gets a large poster board and colored markers to construct a mind map of "Interdependent Relationships in Ecosystems" (students are familiar with mind maps as a result of Mr. Coles collaboration with the ELA teacher). The students have 25 minutes to complete their maps. During this time Mr. Coles circulates among groups and answers questions. When the maps are completed, students did a quick gallery walk of the posters. Next, Mr. Coles distributes the review sheets for the chapter test with all the important ideas from the unit along with the vocabulary from the Word Wall. Students are told that the test will be a performance task in which they will be presented with a scenario and data, and will have to apply their science knowledge to answer a series of questions. Mr. Coles goes over the review sheets, answers questions, and reviews specific concepts as necessary.

Teacher Scenario B: Ms. Rivera

Background

Ms. Rivera teaches middle school science at the same school as Mr. Coles. The district has developed a K-12 scope and sequence, a pacing guide, and has recommended a textbook for teachers to use to plan for instruction. The school is focused on using best practices in teaching that support improved learning and achievement for all students. Since the school is also asking teachers to use data to inform instruction, the science department has agreed to give common assessments – end-of-unit chapter tests that all students in the same course take no matter which teacher they have – so that teachers can learn from the data.

Ms. Rivera attended a summer professional development institute along with other teachers from her school. The teachers are working together through their school-based professional learning community to implement the ideas and strategies learned during the institute. Ms. Rivera and Mr. Coles attended different institutes and are part of different working groups.

Lesson 1

Ms. Rivera starts the lesson by asking students to briefly describe what animals and plants need in order to live and grow. This was something they had already learned in elementary school. After students list food, air and water, Ms. Rivera presents them with the guiding question for the lesson: "How do living things, including humans, interact with each other and with non-living things in an environment?" To generate interest in the topic, she invites students to think about a local environment near their school (such as a playground, park, or garden) and to list the possible interactions among the living and non-living things in that area. Students chart their responses, and compare their lists to other groups' lists. Ms. Rivera then shows a video about the wolves in Yellowstone National Park. Students learn that all the wolves were gone from the park by 1930 due to overhunting, but that these animals were reintroduced into the park in 1995. In pairs, students discuss how reintroducing the wolves might affect the park and the tourists, cattle ranchers, and local residents who live nearby. Ms. Rivera asks students if they think the wolves stay within park boundaries. As a class they list other animals that live in Yellowstone based on what they saw in the video, and discuss how the wolf presence might affect the numbers and distribution of these other animals. Lastly, Ms. Rivera asks students to consider whether people should be allowed to hunt wolves, and whether people should act to restore wild ecosystems. She concludes the lesson by charting students' questions about the interactions between animals and people in Yellowstone, and tells them that in their next lesson, they will start thinking about the kinds of patterns there might be in the ways that organisms interact.

Lesson 2

To begin the lesson, Ms. Rivera asks students to review the list of Yellowstone organisms they had generated in the previous lesson. She has them describe how the animals interact, and begins to construct a simple model of these interactions--a food web--based on student ideas. Ms. Rivera tells them that today they will be exploring the effect of the reintroduction of wolves on the food web in Yellowstone National Park. She shares the guiding question, "What impact can an organism have on the interactions between other organisms in a food web?" Students receive Yellowstone Food Web cards for certain organisms and are asked to put the cards into groups and explain their groupings. Next they arrange the cards into a food web and record it in their science notebooks. They compare their food webs with those of other groups and reflect on similarities and differences. Then Ms. Rivera gives students an information sheet that lists what the various organisms in the food web eat. Students revise their food webs according to the new information and record their revisions. In their groups they discuss the patterns of interaction among the organisms in the food web. Ms. Rivera asks: "Which organisms play a similar role?" "What do you predict would happen to the food web if all the plants died?" Finally, she gives students the Gray Wolf food web card, and has them revise their models again and predict how the wolf might affect the food web. Bacteria, humans and cattle are also added to the food web. At the end of class, Ms. Rivera gives students reflection questions and asks them to describe the patterns of interactions in the food web: "Which animals eat other animals for food?" "Which animals compete for the same food?" "What is an example of a helpful relationship between two animals?" In the last few minutes, students revisit their local ecosystem from the first lesson to reflect on how the food web there might be similar or different from the Yellowstone food web. Their homework is to record their ideas.

Lesson 3

After checking homework, Ms. Rivera tells students that today's lesson, like the previous lesson, will focus on the patterns of interactions among organisms. She has students share some examples of Yellowstone food web interactions from the previous lesson and tells students that now they will be learning scientific terms for some of these interactions. She shares the guiding question "What types of interactions occur between organisms?" Students watch three videos about patterns of interactions between organisms: one about *predator-prey*, one about *competition*, and the last about *symbiosis* (including *mutualism*, *commensalism* and *parasitism*). After each video, students record definitions of the terms onto a note-taking sheet, and list the organisms from the video. Ms. Rivera gives them a reading with information similar to what was in the videos, and students revise their definitions and list additional examples of organisms that follow each pattern of interaction. During the remaining part of the lesson, students work on identifying the patterns of relationships from the Yellowstone food web using the new scientific terms. Ms. Rivera asks students to explain how humans interact with other organisms in predator-prey, competitive, and mutualistic relationships. At the end of class, Ms. Rivera engages students in a discussion comparing the impact of humans on the Yellowstone food web before and after 1994, asking them to use their new terms.

Lesson 4

Ms. Rivera tells students that they will shift from thinking about individual organisms to thinking about populations of organisms. She shares the guiding question for the lesson, "How do living *and* non-living factors affect populations?" In the first part of the lesson, Ms. Rivera asks students to reflect on the interactions among organisms in Yellowstone. Students turn-and-talk with a partner about what kinds of data might help them learn more about the patterns of interactions they were studying in the previous lesson. Students identify wolves and elk as a predator-prey interaction and ask for more information about the quantity of each species in the park over time. They predict that the data will show an increase in wolves and a decrease in the elk since 1994. Ms. Rivera provides students with data, which they plot on graph paper. As students look at their graphs, Ms. Rivera suggest they think about what may have caused the fluctuations they were observing (the *overall* pattern does show the trend they predicted, but the data is more complex than they expected). She reminds them of the guiding question, and suggests they look at another factor that might have affected the elk population--snow accumulation. Students briefly discuss what they expect to see in the data and then graph the snow data with the elk population data. Ms. Rivera encourages her students to make sense of the data through discussion, asking what may have caused these patterns and trends to occur. She concludes the lesson by telling them that they will continue to think about the wolves in Yellowstone in the next lesson. For homework they have to write a paragraph summarizing how their graphs helped them answer that day's guiding question.

<u>*Lesson 5*</u>

Ms. Rivera begins the lesson by asking students to summarize the story of the wolves in Yellowstone. Students recount that humans killed the wolves due to concerns about their effect on wildlife, pets and human safety; that after the wolves were reintroduced they increased in number; and that their predator-prey relationship with the elk caused an overall decrease in the elk population. Next Ms. Rivera shares a reading about the growing population of wolves in the greater Yellowstone region, and the concern about the wolves eating not just elk but also deer, moose, bison and sometimes even livestock and pets. The reading introduces the terms *ecosystem*, *biotic* and *abiotic.* Ms. Rivera has students consider the guiding question, "Does reducing a predator population have a positive or negative impact on an ecosystem?" Students discuss what additional data would be helpful to address this question. Ms. Rivera provides them with data that show the increase in population of some of the other organisms in the Yellowstone food web (birds, plants, etc.). Students say that they think this was due to the decrease in the elk they had observed in the data from their previous lesson. Ms. Rivera then shares a graph that displays four sets of data: the estimated wolf population from 2004-2014, the wolf population at the end of each year, the total number of wolf deaths caused by humans, and the total number of livestock and pets killed by wolves. An argument question is then posted on the wall: "Did wolf deaths caused by humans (ranchers, hunters and park rangers) have a positive or negative impact on the greater Yellowstone ecosystem?" Ms. Rivera posts the positive claim on one side of the room and the negative claim on the other, and students participate in a walking debate in which they move to the side of the room with the claim they think is best supported by the evidence; they are allowed to switch sides at any time. Ms. Rivera had previously introduced accountable talk to her class and has students discuss why their evidence best supports their side of the argument. The homework that night is for students to summarize the best lines of evidence they heard during the walking argument activity.

<u>*Lesson 6*</u>

Ms. Rivera begins the lesson by telling students that people are considering reintroducing the wolf into the northeastern United States. She shares the guiding question for the day: "What is the impact of reintroducing a predator in an ecosystem that also includes humans?" and asks students to identify the information they will need to answer this question. Students respond that they would need background knowledge about the ecosystem, data about existing populations including humans, and more information about the patterns of interactions among those factors. Ms. Rivera tells students that the focus of the lesson is to construct scientific explanations about how the reintroduction of wolves might affect the ecosystem in the Adirondacks. To support their investigation, she gives them a graphic organizer called the Explanation Tool and reviews the components of the Tool. Students gather in pairs to discuss a reading about populations of white-tail deer over time in the U.S., how humans have affected the population, and the variety of negative impacts that increased populations of deer are having on the ecosystem (both biotic and abiotic factors). The first part of the task has students construct an explanation about the effect of large populations of deer on the forest ecosystem in the Adirondacks using quantitative evidence from the reading. The second part has them construct an explanation that predicts the impact that the reintroduction of wolves in the Adirondacks might have on an ecosystem that includes humans, using their knowledge about patterns in ecosystems that they learned from studying the organisms in Yellowstone. Students are able to identify patterns of interaction in the Adirondack ecosystem using the reading and the data, and to identify the cause and effect relationships that help them predict the impact wolves might have on the deer *and* human populations in the Adirondack ecosystem.

Lesson 7

Ms. Rivera explains that the lesson will be divided into two parts. In Part 1, she shares the guiding question: “What are the patterns of interactions between biotic and abiotic factors that affect ecosystems?” Students work in groups to identify the patterns of interaction in a variety of scenarios to explain the impact of one population on another (including predator-prey, competition and symbiosis), and the impact of abiotic factors on a population. In Part 2 students are presented with the claim “Humans impact ecosystems,” and Ms. Rivera has them construct an argument using evidence and reasoning from their previous lessons to support or refute this claim. After the discussion, Ms. Rivera has students reflect with a partner on how their thinking about ecosystems has changed since the first lesson. She concludes the class by reminding students that they would be given a grade-level common assessment for the unit during the following class period. Students are told that the test will be a performance task in which they will be presented with a scenario and data, and will have to apply their science knowledge to answer a series of questions. She suggests they review what they had written in their science notebooks and scaffolds throughout the lessons, as well as what they had recorded from the various activities done during the unit.

Coherent Instructional Sequences Based on Anchor Phenomena

Coherence is one characteristic of high-quality “units of instruction” and is evident at the lesson level, unit level, and program level. These units of instruction are coherent when the components (e.g., parts of a lesson, lesson, chapter, module) begin by considering students’ prior knowledge and experiences then build toward more sophisticated outcomes across the three dimensions (science and engineering practices [SEPs], disciplinary core ideas [DCIs], and crosscutting concepts [CCCs]) and toward a performance expectation (PE) or bundle of PEs. Planning coherent instructional sequences requires clearly defined learning goals and outcomes, carefully sequenced concepts, and the selection of activities and classroom assessments well matched to the learning goals (BSCS, 2016).

The NGSS call for phenomena-based or problem-based instructional sequences that situate learning in motivating and engaging contexts. The outcome of this work is that students use the SEPs, DCIs, and CCCs to explain these phenomena or solve problems. A number of different authors have contributed to thinking about the practical aspects of planning for instruction with a focus on explaining phenomena or solving problems (Penuel & Bell, 2016; Ambitious Science Teaching, 2016). In the Five Tools, we draw from the work of Penuel and Bell (2016) and refer to these phenomena or problems as “anchors”. An anchor phenomenon or problem can guide the planning of one lesson or a series of lessons. In this way, the anchor(s) contributes to coherence within and across lessons.

For purposes of our Five Tools work, we differentiate general phenomena, concepts, guiding questions, and anchor phenomena.

	Phenomenon	Concept	Anchor phenomenon	Guiding question
Definition	A natural phenomenon is an occurrence or situation in nature that is observed to exist or happen and whose cause or explanation is in question.	A concept is a complete sentence that shows a relationship between important science ideas.	An anchor phenomenon is a natural phenomenon that compels students to explain what happens or how it happens.	A question that students might ask as they wonder about an anchor phenomenon
Examples	While the individual organisms in different environments may vary, the patterns of interactions (relationships) between organisms are consistent across different environments.	While the individual organisms in different environments may vary, the patterns of interactions (relationships) between organisms are consistent across different environments. These relationships among organisms, including humans, can be predatory, competitive, or mutually beneficial.	Wolves, reintroduced to Yellowstone in 1999, have established a new “balance of power” in the ecosystem.	Why did wolves disappear from the Yellowstone ecosystem and why were they reintroduced? What effect did the reintroduction of wolves have on the Yellowstone ecosystem?
Comments	Notice that the phenomenon is the same as the concept. This isn’t always the case.		Notice that the anchor phenomenon is a specific example of the general phenomenon or concept.	Note that the guiding questions may include why, how, and what types of questions.
Examples	Respiration rates and heart rates change to maintain homeostasis.	Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy to support cell functions. In these processes, complex molecules containing carbon react	A person from the coast is breathing hard and has a fast heart rate while hiking in the mountains of Colorado.	What makes this happen?

	Phenomenon	Concept	Anchor phenomenon	Guiding question
		with oxygen to produce carbon dioxide and other materials. Blood transfers oxygen and carbon dioxide to and from the lungs and through the body. Oxygen levels are lower at higher altitudes, so the body increases heart rate and breathing rate to maintain oxygen levels throughout the body needed for cellular respiration.		
Comments	The phenomenon in this example is the general pattern implied by the anchor phenomenon.	Notice that several concepts are required to fully explain the phenomenon and the anchor phenomenon.	The anchor phenomenon is a specific example of the phenomenon.	None.

According to Penuel and Bell (2016), a good anchor builds upon everyday experiences of students—who they are, what they do, and where they came from—and is compelling for *all* students, including English language learners and students from cultural groups underrepresented in STEM.

- A good anchor phenomenon will require students to develop understandings and applications of multiple NGSS performance expectations while also engaging in related acts of mathematics, reading, writing, and communication. It has relevant data, images, and text to engage students in the range of ideas students need to understand. It should allow them to use a broad sequence of science and engineering practices to learn science through firsthand or secondhand investigations.
- A good anchor phenomenon is too complex for students to explain or design a solution for after a single lesson. The explanation or solution is just beyond the reach of what students can figure out without instruction. Searching online will not yield a quick answer for students to copy.
- A good anchor phenomenon is observable by students with their senses or technological devices to see things at very large and very small scales (telescopes, microscopes), video presentations, demonstrations, or surface patterns in data.
- A good anchor phenomenon can be a case (e.g., well-described problem) or something that is puzzling and prompts students to ask questions.
- A good anchor phenomenon is of interest to an audience or stakeholder community that cares about the findings or products. (Penuel & Bell, 2016)

Citations

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NGSS Innovations

By Rodger W. Bybee

The architecture of the NGSS differs significantly from prior standards for science education. In the NGSS, the three dimensions of Science and Engineering Practices (SEPs), Disciplinary Core Ideas (DCIs), and Crosscutting Concepts (CCCs) are crafted into performance expectations that describe what is to be assessable following instruction. The NGSS performance expectations are therefore a measure of competency. The foundation boxes for each of the three dimensions provide additional information and clarity for the design or redesign of school programs.

A comprehensive program should provide opportunities for students to develop their understanding of DCIs through their engagement in SEPs and their application of CCCs. This three-dimensional learning leads to eventual mastery of performance expectations. In this perspective, a quality program should clearly describe or show how the cumulative learning experience works coherently with previous and following experiences to build scientific literacy.

The following innovations in the NGSS are hallmarks of current thinking about how students learn science, and they set a vision for future science education. These innovations will not only cause a shift in instructional programs in American classrooms but should also affect and refocus the efforts of curriculum developers and the design of comprehensive school science programs.

Innovation 1: K–12 science education reflects three-dimensional learning.

In the NGSS, science is described as having three distinct dimensions, each of which represents equally important learning outcomes: (1) SEPs, (2) DCIs, and (3) CCCs (The Next Generation Science Standards 2013). The NGSS expectations for students include making connections among all three dimensions. Students develop and apply the skills and abilities described in the SEP, as well as learn to make connections between different DCIs through the CCC to help gain a better understanding of the natural and designed world. Current research suggests that both knowledge (DCIs and CCCs) and practice (SEPs) are necessary for a full understanding of science.

Each NGSS standard integrates one specific SEP, CCC, and DCI into a performance expectation that details what students should be proficient in by the end of instruction. In past standards the separation of skills and knowledge often led to an emphasis (in both instruction and assessment) on science concepts and an omission of inquiry and practices. It is important to note that the NGSS performance expectations do not specify or limit the intersection of the three dimensions in classroom instruction. Multiple SEPs, CCCs, and DCIs that blend and work together in several contexts will be needed to help students build toward competency in the targeted performance expectations. For example, if the end goal (the performance expectation) for students is to plan an investigation to determine the causes and effects of plant growth (2-LS2-1), they can build toward this goal through asking good questions about patterns that they have seen in plant growth and engaging in argument about what kinds of data would be important to collect in an investigation to answer these questions.

It should also be noted that one performance expectation should not be equated to one lesson. Performance expectations define the three-dimensional learning expectations for students, and it is unlikely that a single lesson would provide adequate opportunities for a student to demonstrate proficiency in every dimension of a performance expectation. A series of high-quality lessons or a unit in a program are more likely to provide these opportunities.

School programs must change:

From: providing discrete facts and concepts in science disciplines, with limited application of practice or the interconnected nature of the disciplines. Where crosscutting themes were included, they were implicit and not noticed or used by the student. Assessments within the programs exclusively addressed disciplinary concepts of science; neither the processes, inquiry, or SEPs nor the CCCs, unifying themes, or big ideas were included in the assessments.

To: providing learning experiences for students that blend multiple SEPs, CCCs, and DCIs — even those SEPs, CCCs, and DCIs not specified within the targeted performance expectations — with the goal that students are actively engaged in scientific processes to develop an understanding of each of the three dimensions. CCCs are included explicitly, and students learn to use them as tools to make sense of phenomena and make connections across disciplines. Assessments within the programs reflect each of the three distinct dimensions of science *and their interconnectedness*.

Innovation 2: Students engage in explaining phenomena and designing solutions.

In educational programs aligned to the NGSS, the goal of instruction is not solely for students to memorize content. Content becomes meaningful to students when they see its usefulness — when they need it to answer a question. Therefore, in programs aligned to the NGSS, an important component of instruction is to pique students' curiosity to help them see a need for the content.

The ultimate goal of an NGSS-aligned science education is for students to be able to explain real-world phenomena and to design solutions to problems using their understanding of the DCIs, CCCs, and SEPs. Students also develop their understanding of the DCIs by engaging in the SEPs and applying the CCCs. These three dimensions are tools that students can acquire and use to answer questions about the world around them and to solve design problems.

School programs must change:

From: focusing on disconnected topics, with content treated as an end in itself.

To: focusing on engaging students with meaningful phenomena or problems that can be explained or solved through the application of SEPs, CCCs, and DCIs. Instructional units that focus on students explaining relevant phenomena can provide the motivation students need to become invested in their own learning.

Innovation 3: The NGSS incorporate engineering design and the nature of science as SEPs and CCCs.

The NGSS include engineering design and the nature of science as significant elements. Some of the unique aspects of engineering design (e.g., identifying and designing solutions for problems), as well as common aspects of both science and engineering (e.g., designing investigations and communicating information), are incorporated throughout the NGSS as expectations for students from kindergarten through high school. In addition, unique aspects of the nature of science (e.g., scientific investigations use a variety of methods; scientific knowledge is based on empirical evidence; science is a way of knowing; science is a human endeavor) are included as SEPs and CCCs throughout the grade bands.

School programs must change:

From: presenting engineering design and the nature of science as supplemental or as disconnected from science learning (e.g., design projects that do not require science knowledge to complete successfully), with neither included in assessments.

To: incorporating learning experiences that include the DCIs of engineering design as well as the SEPs and CCCs of both engineering and the nature of science, with both included in assessments. Both engineering design and the nature of science are taught in an integrated manner with science disciplines (e.g., design projects require science knowledge in order to develop a good solution; the engineering process contributes to building science knowledge).

Innovation 4. SEPs, DCIs, and CCCs build coherent learning progressions from kindergarten to grade 12.

The NGSS provide for sustained opportunities from elementary through high school for students to engage in and develop a progressively deeper understanding of each of the three dimensions. Students require coherent learning progressions both within a grade level and across grade levels so they can continually build on and revise their knowledge to expand their understanding of each of the three dimensions by grade 12.

School programs must change:

From: a curriculum that lacks coherence in knowledge and experiences; provides repetitive, discrete knowledge that students memorize at each grade level; and often misses essential knowledge that has to be filled at later grade levels.

To: providing learning experiences for students that develop a coherent progression of knowledge and skills from elementary through high school. The learning experiences focus on a smaller set of disciplinary concepts that build on what has been learned in previous grades and provide the foundation for learning at the next grade span as detailed in the NGSS learning progressions.

Innovation 5. The NGSS connect to English language arts (ELA) and mathematics.

The NGSS not only provide for coherence in science teaching and learning but also unite science with other relevant classroom subjects: mathematics and ELA. This connection is deliberate because science literacy requires proficiency in mathematical computations and in communication skills. In fact, there are many inherent overlaps in the mathematics, ELA, and science practices. Therefore as the NGSS were being drafted, the writers ensured alignment to and identified some possible connections with the Common Core State Standards for ELA/literacy and mathematics as an example of ways to connect the three subjects. In instruction within the science classroom, mathematical and linguistic skills can be applied and enhanced to ensure a symbiotic pace of learning in all content areas. This meaningful and substantive overlapping of skills and knowledge helps provide all students equitable with access to the learning standards for science, math, and literacy. The fact that science can be connected to the "basics" should not go unnoticed. Indeed, it presents science as a basic.

School programs must change:

From: providing siloed science knowledge that students learn in isolation from reading, writing, and arithmetic — the historical "basic" knowledge.

To: providing science learning experiences for students that explicitly connect to mathematics and ELA learning in meaningful and substantive ways and that provide broad and deep conceptual understanding in all three subject areas.

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to describe phenomena. (MS-LS2-3)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Analyze and interpret data to provide evidence for phenomena. (MS-LS2-1)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena. (MS-LS2-2)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).
- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-LS2-4)
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-LS2-5)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science disciplines share common rules of obtaining and evaluating empirical evidence. (MS-LS2-4)

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1)
- Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (MS-LS2-2)

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)

LS4.D: Biodiversity and Humans
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (*secondary to MS-LS2-5*)

ETS1.B: Developing Possible Solutions
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. *(secondary to MS-LS2-5)*

Crosscutting Concepts

Patterns
- Patterns can be used to identify cause and effect relationships. (MS-LS2-2)

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)

Energy and Matter
- The transfer of energy can be tracked as energy flows through a natural system. (MS-LS2-3)

Stability and Change
- Small changes in one part of a system might cause large changes in another part. (MS-LS2-4),(MS-LS2-5)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
- The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-LS2-5)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-LS2-3)

Science Addresses Questions About the Natural and Material World
- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-LS2-5)

Connections to other DCIs in this grade-band: **MS.PS1.B** (MS-LS2-3); **MS.LS1.B** (MS-LS2-2); **MS.LS4.C** (MS-LS2-4); **MS.LS4.D** (MS-LS2-4); **MS.ESS2.A** (MS-LS2-3),(MS-LS2-4); **MS.ESS3.A** (MS-LS2-1),(MS-LS2-4); **MS.ESS3.C** (MS-LS2-1),(MS-LS2-4),(MS-LS2-5)

Articulation across grade-bands: **1.LS1.B** (MS-LS2-2); **3.LS2.C** (MS-LS2-1),(MS-LS2-4); **3.LS4.D** (MS-LS2-1),(MS-LS2-4); **5.LS2.A** (MS-LS2-1),(MS-LS2-3); **5.LS2.B** (MS-LS2-3); **HS.PS3.B** (MS-LS2-3); **HS.LS1.C** (MS-LS2-3); **HS.LS2.A** (MS-LS2-1),(MS-LS2-2),(MS-LS2-5); **HS.LS2.B** (MS-LS2-2),(MS-LS2-3); **HS.LS2.C** (MS-LS2-4),(MS-LS2-5); **HS.LS2.D** (MS-LS2-2); **HS.LS4.C** (MS-LS2-1),(MS-LS2-4); **HS.LS4.D** (MS-LS2-1),(MS-LS2-4),(MS-LS2-5); **HS.ESS2.A** (MS-LS2-3); **HS.ESS2.E** (MS-LS2-4); **HS.ESS3.A** (MS-LS2-1),(MS-LS2-5);

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

HS.ESS3.B (MS-LS2-4); **HS.ESS3.C** (MS-LS2-4),(MS-LS2-5); **HS.ESS3.D** (MS-LS2-5)

Common Core State Standards Connections:

ELA/Literacy –

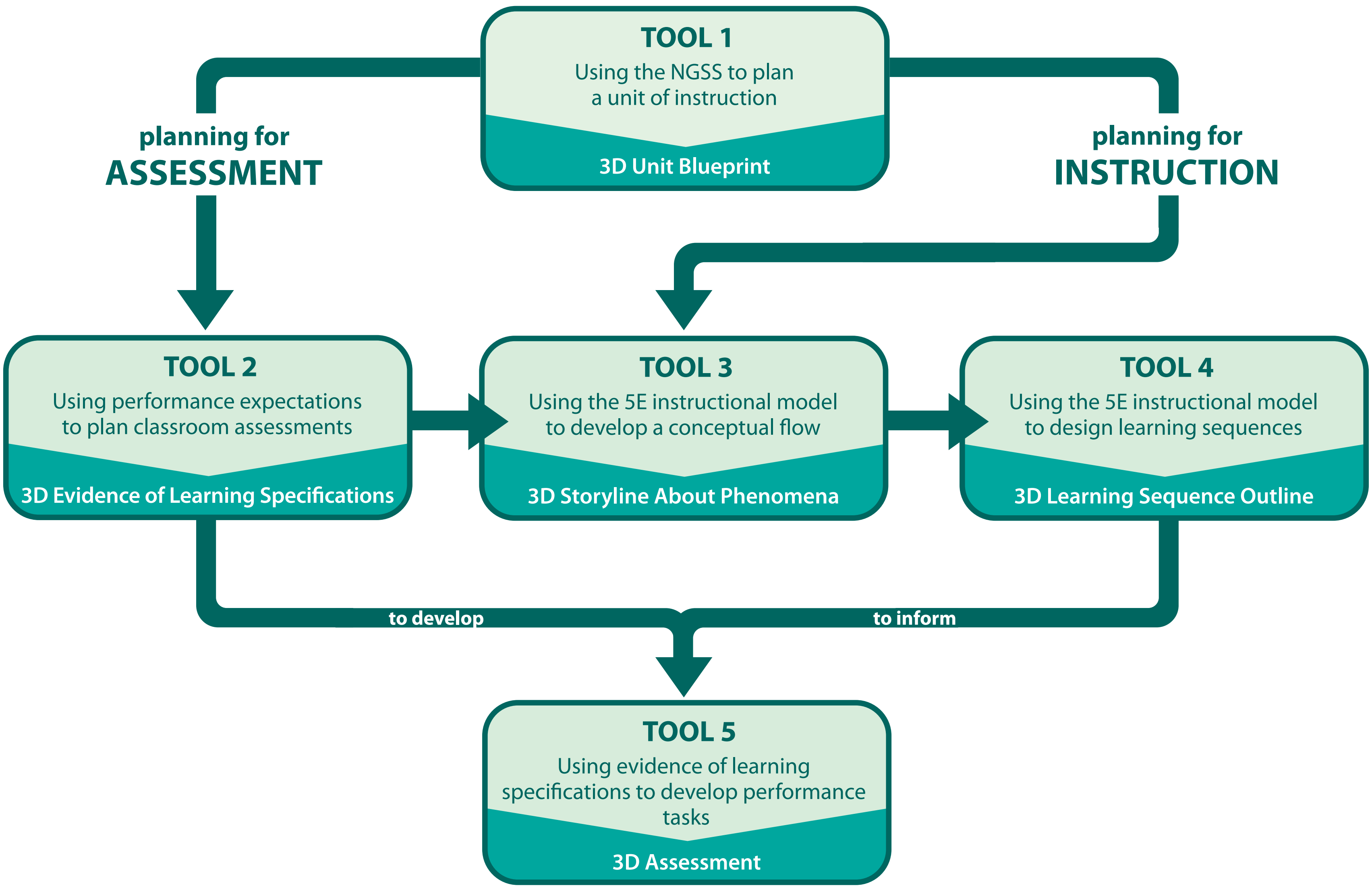
RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. (MS-LS2-1),(MS-LS2-2),(MS-LS2-4)
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-LS2-1)
RST.6-8.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (MS-LS2-5)
RI.8.8	Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims. (MS-LS-4),(MS-LS2-5)
WHST.6-8.1	Write arguments to support claims with clear reasons and relevant evidence. (MS-LS2-4)
WHST.6-8.2	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS2-2)
WHST.6-8.9	Draw evidence from literary or informational texts to support analysis, reflection, and research. (MS-LS2-2),(MS-LS2-4)
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly. *(MS-LS2-2)*
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS2-2)*
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. *(MS-LS2-3)*

Mathematics –

MP.4	Model with mathematics. *(MS-LS2-5)*
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems. *(MS-LS2-5)*
6.EE.C.9	Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. *(MS-LS2-3)*
6.SP.B.5	Summarize numerical data sets in relation to their context. *(MS-LS2-2)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Five Tools and Processes For Translating the NGSS Into Instruction and Classroom Assessment



Analysis and Action Steps

What are the *challenges* for Teachers and PD Leaders in translating the NGSS into effective phenomena-focused three-dimensional instruction and assessment?	What *supports* do Teachers and PD Leaders need to translate the NGSS into effective phenomena-focused three-dimensional instruction and assessment?

What are your *next steps* as a building or district leader?

BSCS

I Can Use the Identify and Interpret (I^2) Strategy

Have you ever looked at a graph or figure and felt overwhelmed by it? Often there is a lot of information on graphs and in figures. The Identify and Interpret (I^2) strategy helps you make sense of graphs, figures, sketches, and other ways to represent data. This strategy helps you break down the information into smaller parts. To do this, you first *identify* what you see in the graph or figure. Then you *interpret* each of those observations by deciding what they mean.

Once you have determined what the smaller parts of the graph or figure mean, you are ready to put all the information together. To do this, you write a *caption*. You have probably seen captions under figures in textbooks or magazines. Captions are a summary of the information in the graph or figure. They are written in complete sentences. Captions help you show your understanding of the material you are studying.

To help you understand how to use the I^2 strategy, look at the following example. This example will help you make sense of a graph. This graph shows the average monthly temperatures in one US city.

<table>
<tr><th>I^2 step</th><th>Example</th></tr>
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Step 1: Identify
("What I see" comments)

- Identify any changes, trends, or differences you see in the graph or figure.
- Draw arrows and write a "What I see" comment for each arrow.
- Be concise in your comments. These should be just what you can observe.
- Do not try to explain the meaning at this point.

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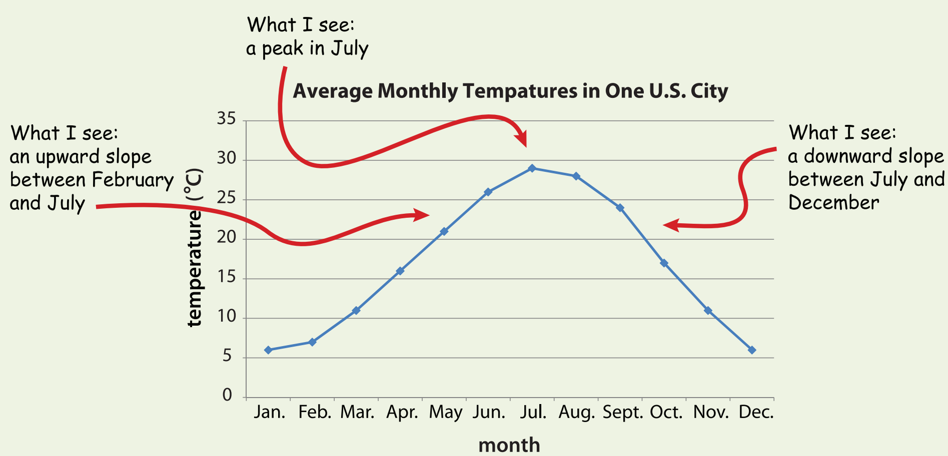

For this example, there are arrows drawn that point to the two trends and the change. Notice that the arrows point to the general upward and downward trends, not to each data point. A "What I see" comment describes what each arrow points to on the graph.

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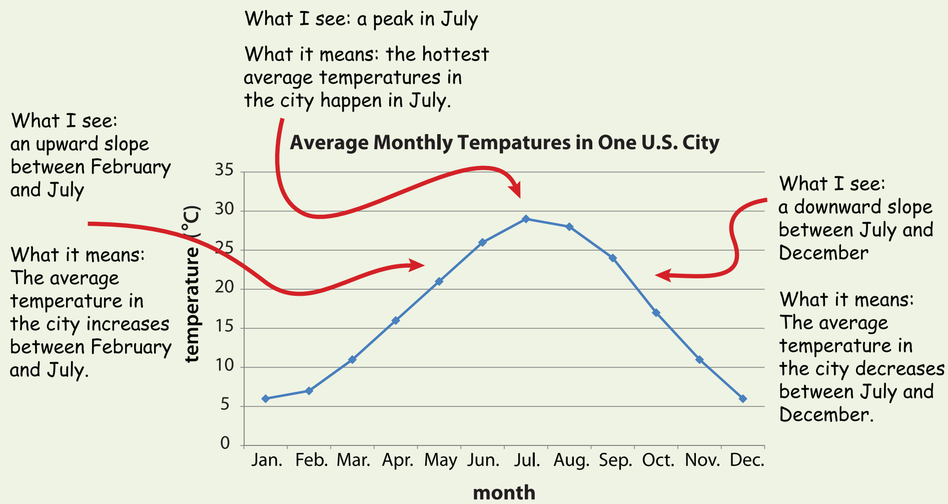
I^2 step	Example

Step 2: Interpret ("What it means" comments)

- Interpret the meaning of each "What I see" comment by writing a "What it means" comment.
- Do not try to interpret the whole graph or figure.

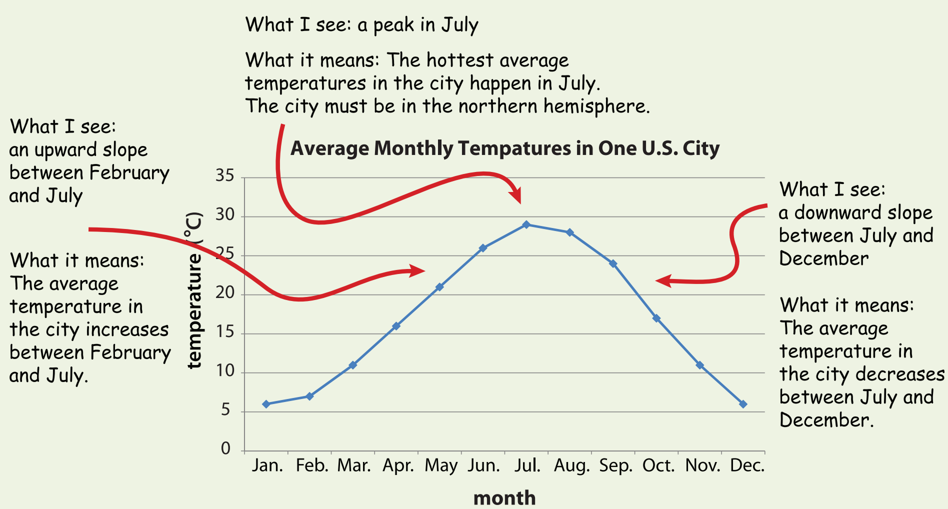


In this example, "What it means" comments were added to each "What I see" comment. The "What it means" comments explain the changes, trends, and differences that were identified in Step 1.

I^2 step	Example

Step 3: Caption

- Write a caption for the graph or figure.
- Start with a topic sentence that describes what the graph or figure shows.
- Then join each "What I see" comment with its "What it means" comment to make a sentence.
- Build a coherent paragraph out of your sentences.



This graph shows the average temperature in a city over a year. There is an upward slope from February to July, showing that there is an increase in the average temperature during these months. There is a downward slope from July to December, which means the average temperature decreases during this time. There is a peak in July, which shows that the hottest average temperature in the city happens in July. The peak in July also means that the city must be in the Northern Hemisphere.

In this example, the first sentence of the caption describes what the graph shows. Then each "What I see" comment was combined with its "What it means" comment to form complete sentences. Those sentences make up a paragraph that describes each part of the graph.

I Can Use the Identify and Interpret (I^2) Strategy

Teacher

Students can become overwhelmed when they try to interpret graphs, figures, or data tables. The Identify and Interpret (I^2) strategy is a way to help students make sense of the information by breaking it down into smaller parts.

In the I^2 strategy, students first *identify* changes, trends, or differences. They draw an arrow to each observation and then write a "What I see" (WIS) comment. These comments should simply be what the student observes, such as a positive slope on a graph or increasing numbers in a data table. After students have made all their observations and written their WIS comments, they should *interpret* the meaning of their observations by writing a "What it means" (WIM) comment for each. Once students have mastered WIS and WIM comments, ask them to create a caption for the graph, figure, or table. A caption is a summary of all the information and helps show students' understanding.

To use the I^2 strategy, you should have students place the graph, figure, or table that they are interpreting into their science notebooks. They should then draw the arrows and write their comments on and around the image. This helps them make the connections between the graphical information and their ideas. They should write the caption on the same page to help remind them of the interpretation.

Help students with page management as you use the strategy. Remind them to leave plenty of room around the graph, figure, or table so they can write their WIS and WIM comments. Also make sure they have room below the graph or figure to write their captions.

When you first begin using this strategy, model it for students. They can benefit greatly from watching you do a "think-aloud" as you complete the strategy on a graph, figure, or table. In the beginning, only ask students to complete the WIS and WIM comments without writing a caption. They will likely need help understanding what they should be looking for on the graph. Some students do not add enough arrows and WIS comments to interpret all the information. Other students try to add as many arrows and WIS comments as possible. These students soon find that they cannot interpret the meaning of some of their WIS comments. For example, if they identify that a graph is printed in black ink, they will discover that they cannot assign meaning to this WIS comment. This stage helps students begin to filter their numerous observations and only identify those that are significant to the graph, figure, or table.

Once students have become proficient at writing WIS and WIM comments, ask them to add a caption. Some students will find it repetitive since they are joining the WIS and WIM comments to create most of their captions; however, help them realize that the ability to create a coherent paragraph that interprets all parts of a graph, figure, or table is an important skill in science and other subjects. Later, when students have had a great deal of practice with this strategy, the ultimate goal should be for them to write a caption without having to list their WIS and WIM comments. Eventually, these comments become a habit of mind, and students should be able to notice all the pieces of a graph or figure to come up with a complete interpretation. Developing these habits of mind to identify and interpret data in many forms is a skill that will benefit students in all subjects, in their jobs as they get older, and in becoming a scientifically literate citizen.