Chapter 4
Grades Three Through Five

2016 Science Framework

FOR CALIFORNIA PUBLIC SCHOOLS
Kindergarten Through Grade Twelve

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To view the remaining sections of the 2016 California Science Framework on the CDE website, go to:
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Items in this document that relate to crosscutting concepts are highlighted in green and followed by the abbreviation CCC in brackets, **[CCC]**, with a number corresponding to the concept. The same items that correspond to the science and engineering practices are highlighted in blue and followed by the abbreviation SEP in brackets, **[SEP]**, with a number corresponding to the practice.

The Web links in this document have been replaced with links that redirect the reader to a California Department of Education (CDE) Web page containing the actual Web addresses and short descriptions. Here the reader can access the Web page referenced in the text. This approach allows CDE to ensure the links remain current.

Grades Three Through Five

Introduction to Grades Three Through Five

Students in [third] through fifth grade begin to develop an understanding of the four disciplinary core ideas: physical sciences; life sciences; Earth and space sciences; and engineering, technology, and applications of science. In the earlier grades, students begin by recognizing patterns and formulating answers to questions about the world around them. . . .

The performance expectations in elementary school grade bands develop ideas and skills that will allow students to explain more complex phenomena in the four disciplines as they progress to middle school and high school. While the performance expectations shown in [third] through fifth grade couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices that lead to the performance expectations.

— NGSS Lead States 2013 , Next Generation Science Standards For States, By States

The upper elementary grades employ **science and engineering practices (SEP)** to explore the natural world. The SEPs, like all three dimensions of the California Next Generation Science Standards (CA NGSS), build in complexity in an age-appropriate manner and look very different in grades three through five than they do in grades six through eight and in high school. Appendix 1 of this framework outlines these progressions for each dimension. Students use these practices to understand everyday life events (*phenomena*), and CA NGSS-aligned instruction should begin with and be based around these real-world experiences. In particular, instruction in grades three through five focuses on describing specific evidence of **patterns [CCC-1]** in phenomena, linking those patterns to **cause and effect relationships [CCC-2]**, and then beginning to **construct explanations [SEP-6]** and **models [SEP-2]** that generalize those findings.

The CA NGSS do not specify which phenomena to explore or the order to address topics because phenomena need to be relevant to the students that live in each community and should flow in an authentic manner. This chapter illustrates one possible set of phenomena that will help students achieve the CA NGSS performance expectations. The phenomena chosen for this statewide document will not be ideal for every classroom in a state as large and diverse as California. Teachers are therefore encouraged to select phenomena that will engage their students and use this chapter's examples as inspiration for designing their own instructional sequence.

In this framework, overarching phenomena that frame entire sequences of instruction are called *anchoring phenomena* while smaller and more focused phenomena are called *investigative phenomena*. While all phenomena ideally should be relevant to each student's life, culture, and experience, sometimes instruction draws attention to specific events that occur as *everyday phenomena*. Some phenomena introduce challenges that require engineering solutions, and in these cases it makes sense to focus on the anchor, investigative, or everyday problem rather than the phenomenon itself.

In this chapter's examples, each year is divided into instructional segments (IS) centered on questions about observations of a specific phenomenon. Different phenomena require different amounts of time to investigate, explore, and understand, so each instructional segment should take a different fraction of the school year. As students achieve the performance expectations within each instructional segment, they uncover **disciplinary core ideas (DCIs)** from different fields of science (physical science, life science, and Earth and space science) and engineering. Students engage in multiple practices in each instructional segment, not only those explicitly indicated in the performance expectations. Students also focus on one or two **crosscutting concepts (CCCs)** as tools to make sense of their observations and investigations; the CCCs are recurring themes in all disciplines of science and engineering and help tie these seemingly disparate fields together. As students explore their environment during this grade span, they develop their growing understanding of the interconnections and interdependence of Earth's natural systems and human social systems as outlined in California's Environmental Principles and Concepts (EP&Cs). All three of the CA NGSS dimensions and the EP&Cs will prepare students to make decisions about California's future and become sources of innovative solutions to the problems the state may face in the future.

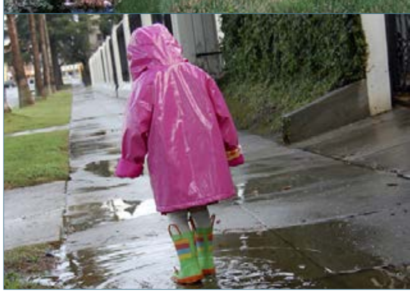
The SEPs, DCIs, and CCCs grow in sophistication and complexity throughout the K–12 sequence. While this chapter calls out examples of the three dimensions in the text using color-coding along with the three-letter abbreviations, each element should be interpreted with this grade-appropriate complexity in mind (appendix 1 of this framework clarifies the expectations at each grade span in the developmental progression).

Grade Three

In many cases, grade three returns to some of the same disciplinary core ideas (DCIs) and phenomena as kindergarten but revisits them with a more sophisticated application of the science and engineering practices (SEPs). Table 4.1 shows a sequence of four possible phenomenon-based instructional segments in grade three. Instructional segment 1 revisits concepts of forces and motion that are nearly identical to kindergarten, but now it includes the added conceptual complexity of the effects of multiple forces. In kindergarten, it was sufficient for students to develop mental models (intuition), and now in grade three students learn tools for articulating those **models [SEP-2]** using diagrams of forces and motion. In IS2, students revisit their **argument [SEP-7]** from kindergarten that children look similar but not identical to their parents; but they now must document more detailed evidence by **analyzing and interpreting [SEP-4]** specific data. Instructional segment 3 helps students understand how the environment influences plants and animals, which is a mirror to the kindergarten concept that plants and animals can influence and modify their environment (California's Environmental Principles and Concepts [EP&Cs I, II]). Instructional segment 4 looks at weather patterns just like students did in kindergarten, but now it involves more **mathematical thinking [SEP-5]** in which students **analyze [SEP-4]** quantitative **measurements [CCC-3]** and adds a greater focus on the impacts of weather events on humans.

Patterns [CCC-1] and **cause and effect [CCC-2]** remain the key focus of grade three, with students using patterns as evidence that there must be a specific cause and effect relationship. The **explanations [SEP-6]** that students construct are still largely descriptions of what happened (evidence-based accounts), rather than descriptions of the invisible mechanisms that cause things to happen (which begins in grades four and five).

Table 4.1. Overview of Instructional Segments for Grade Three

	**1 Playground Forces** Students investigate the effects of forces on the motion of playground objects like balls and swings. They use pictorial models to describe multiple forces on objects and predict how they will move as those forces change. They ask questions about how electric and magnetic forces can act without touching and then use them to solve a problem in a design challenge.
	**2 Life cycle for Survival** Students observe life cycles as well as animals living in groups and then describe how these traits help organisms meet their needs. Students measure different traits to document the differences between offspring, their parents, and other members of their population. Some of these variations make organisms more likely to survive.
	**3 Surviving in Different Environments** Students develop a model of the relationship between traits, environment, and survival. Students collect evidence that organisms live in environments that best meet their needs and that changes in the environment can affect the traits and survival of organisms.
	**4 Weather Impacts** Students record patterns in weather over the school year and then analyze their data. They learn about weather patterns around the world and design solutions to reduce the impacts of weather hazards right in their own schoolyard.

Sources: epSos.de 2010; Mosdell 2012; U.S. Fish and Wildlife Service 2015; mintchipdesigns 2009

IS1

Grade Three Instructional Segment 1: Playground Forces

Children push and pull on objects every day, but they do not actively think about all these forces. Despite the fact that these forces are invisible, the human sense of touch is a built-in sensor for detecting them. In kindergarten, students investigated pushes and pulls and developed a simple model relating the direction and strength of pushes and pulls to the motion of objects. In grade three, they investigate a number of playground phenomena to extend this model to include many different forces acting on objects all at once. They apply the model to predict the motion of objects based on patterns of how they have moved in the past.

GRADE THREE INSTRUCTIONAL SEGMENT 1: PLAYGROUND FORCES

Guiding Questions

- What happens when several different forces push or pull an object at once?
- How can an object be pushed or pulled but not move?
- What do we need to know to predict the motion of objects?
- How can some objects push or pull one another without even touching?

Performance Expectations

Students who demonstrate understanding can do the following:

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and balanced forces pushing on a box from both sides will not produce any motion at all.] [*Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.*]

3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. [Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [*Assessment Boundary: Assessment does not include technical terms such as period and frequency.*]

3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [*Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.*]

3-PS2-4. Define a simple design problem that can be solved by applying ideas about magnets.* [Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.]

3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. [This performance expectation does not have a clarification statement or an assessment boundary.]

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. [This performance expectation does not have a clarification statement or an assessment boundary.]

GRADE THREE INSTRUCTIONAL SEGMENT 1: PLAYGROUND FORCES		
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:		
Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-7] Engaging in Argument from Evidence	PS2.A: Forces and Motion PS2.B: Types of Interactions	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-7] Stability and Change
CA CCSS Math Connections: 3.OA.1–7, MP 5, 6		
CA CCSS for ELA/Literacy Connections: RI.3.4; L.3.4, 5		
CA ELD Standards Connections: ELD.PI.3.1, 5, 12		

Students explore a variety of physical systems in which they can physically feel forces. They kick balls, hang from bars, push one another on the swing, slide down the slide, and land on the ground after leaping from a step on the play structure. Some forces are strong and some are weak. Some cause motion to start while others cause motion to stop. Sometimes, a person can feel multiple forces at the same time (e.g., riding a swing and feeling the seat push their bottom and their friend push their back). While students in kindergarten discussed how pushes and pulls have both strength and direction, this is the first time that the term *force* is explicitly used to describe them. To a physicist, pushes and pulls are both forces, they just act in different directions on an object. This instructional segment introduces students to four key ideas about forces: (1) every object has many forces acting on it at every moment; (2) forces add up, so that the overall effect depends not just on one of them, but on the combination of them; (3) when all the forces on an object equal or balance one another, there is no change in the motion, but the object will speed up, slow down, or change direction when the forces are unbalanced; and (4) some forces can act even when objects are not touching.

Grade Three Snapshot 4.1: Pictorial Models of Forces

Everyday phenomenon: Students feel a force as they kick a ball.

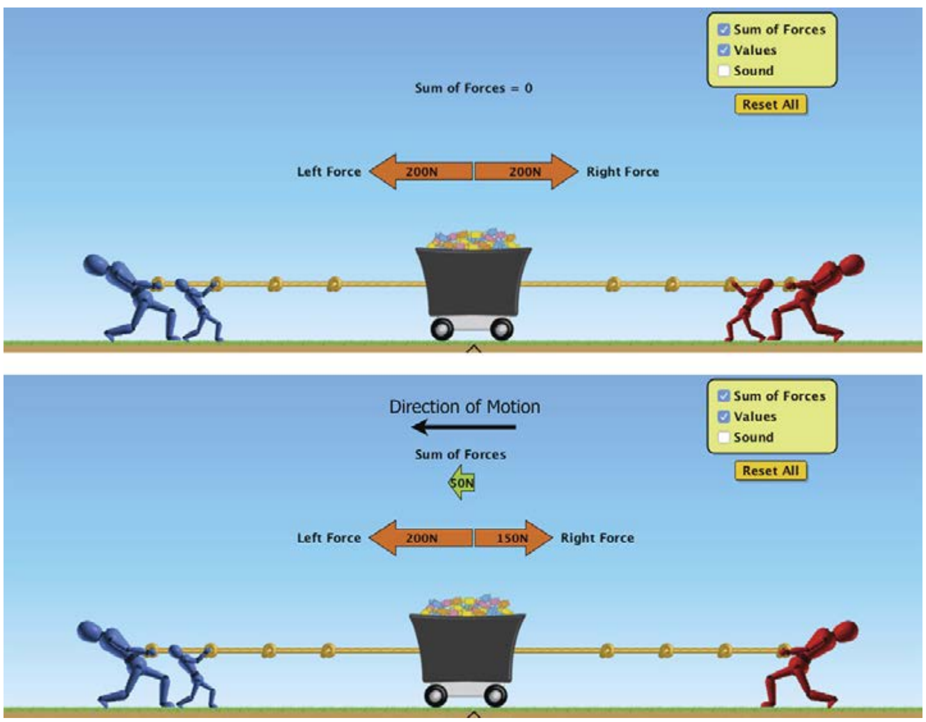
Ms. S took her students out to kick balls on the soccer field so that her students could feel the pressure of the ball against their feet. Did the ball move faster if they kicked it harder?

Investigative phenomenon: A ball sometimes rises off the ground when kicked.

For some students, the ball travelled straight across the ground, but for other kickers the ball rose off the ground and then fell back down. What was it that students were doing differently that caused the ball to fly up for some but not others? Is it just because they kicked the ball harder? Ms. S asked her students to draw two pictures side by side showing the path of the ball in each case. Then, she asked students to use a different arrow to represent the push of the kicker. They were making a **pictorial model [SEP-2]** of the force acting on the ball and its **effect [CCC-2]** on the ball's motion. In many cases, Ms. S's students drew the force arrow horizontally for both cases. Ms. S had students test out ways that they could get the ball to go higher in the air and then describe what they were doing. Eventually the students realized that the ball traveled along the ground when they pushed against the ball mostly horizontally, but when they got under the ball and pushed it slightly upward they could lift the ball in the air—the direction of the ball's motion depended on the direction of the push. They modified their drawings to reflect this change. Ms. S introduced the term *force* for the first time and had students label the arrow in their pictorial model with that word. Ms. S had her students draw pictorial models of forces many times during this instructional segment.

Students can **investigate [SEP-3]** specific situations that illustrate what happens when multiple forces act on an object at once (3-PS2-1). Students can push one another around in cardboard box race cars (see IS4 from kindergarten). What happens when two people push on the box together instead of just one? What happens when one person pushes the box forward while another student pushes it the opposite direction? How about if two people push it forward and only one pushes opposite? Or two people push forward and one person pushes sideways? By drawing **pictorial models [SEP-2]** of each situation, students can illustrate the effects of multiple forces acting on the same object at the same time. Other examples illustrate the same effects. Rather than kicking a ball on an open field, students push a ball against a wall. Can they still feel a force? Why doesn't the ball move? Two students can face one another, place their palms together, and then lean in towards one another. As they each push against one another, they can stay stationary as long as they balance one another with equal forces. If one person pulls away or pushes forward with more force, the system is no longer **stable [CCC-7]** and they move. In a game of tug-of-war, a flag attached to the rope might stay still even though both teams are pulling with strong forces on both sides (figure 4.1, top). But if one team lets go of the rope, the other team goes flying backwards when the force becomes unbalanced. Students can even experiment with a mini tug-of-war in which students pull at different angles on three or four strings attached together. Can they predict what which direction the system will move when one of the strings gets cut?

Figure 4.1. Balancing Forces in a Tug-of-War



Source: Adapted from PhET Interactive Simulations, University of Colorado Boulder (PhET) n.d.b.
Long description of Figure 4.1.

At this point, students should be able to use evidence from their **investigations [SEP-3]** and reasoning from their **model [SEP-2]** of forces to support two essential **claims [SEP-7]**:

- To start an object moving, you need to push or pull it with an unbalanced force.
- An object whose motion is not changing has no forces pushing or pulling it, or all the forces are balanced.

When students have a mental model that incorporates these claims, they can discover some invisible forces that push or pull that they may never have thought of as forces. When letting go of a ball or book, it begins to fall (i.e., start moving). This change in motion is evidence that a force must be acting. Gravity is the unseen force that acts on all objects at all times and causes the book to start moving. There is no way to escape gravity! Even if you travel far away from Earth in a spaceship, you will still always feel the pull of our planet (though it gets weaker as you get farther away). In grade five, students will collect evidence that gravity always acts downward on the surface of the Earth.

But what if a book just sits on a table and is not moving? Does gravity still pull on it? If so, why isn't it moving? A student can place their hand between a heavy book and the table in order to feel both the downward force of the book and the force of the table from below. Students should be able to draw a pictorial model of forces that shows the force of the table pushing upwards to balance out the force of gravity that pulls the book downward (figure 4.2). Students can feel a supporting force pushing their feet while they stand or pushing their bottom while they sit.

Figure 4.2. Student's Model of Balanced Forces Acting on a Book

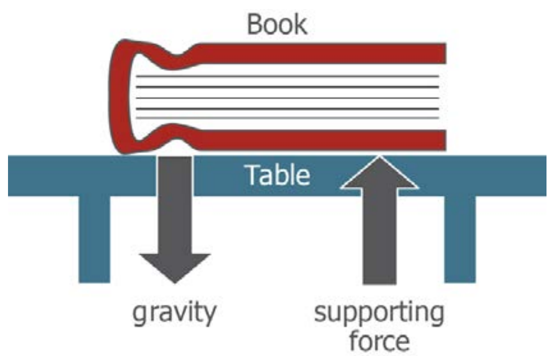


Diagram by M. d'Alessio
[Long description of Figure 4.2.]

Students can also use this model to identify another important invisible force, friction. When a student slides a book across a table, it eventually slows down and stops. A very common incorrect preconception is that the book runs out of energy or requires some sort of *motive* force to keep it in motion, but these ideas are not true. Any time an object slows down, that is evidence that there is a force pushing against the object that causes its motion to change. Students can experiment with the strength of the force of friction by trying to slide books or wooden blocks over a variety of surfaces with different amounts of friction. A book slows down quickly when the force of friction is strong and takes longer to slow down when friction is weak, even when the initial push that starts the motion is the same. Students can draw pictorial models showing different strength arrows representing friction for different surfaces. The force of friction always acts in the direction opposite the direction objects are moving, so it always slows them down. In the middle grades, students will build on this simple model of friction and relate it to energy transfer.

Opportunities for ELA/ELD Connections

During the instructional segment, provide age-appropriate definitions of domain-specific words and important academic vocabulary. In addition, select a few terms critical to understanding the concept. Have students use a graphic organizer so that they can gain a deeper understanding of these key concepts. One such organizer is the Frayer Model, which prompts students to write a definition, and allows for students to discuss specific characteristics of the word, examples, and nonexamples. Sample words for this topic could include *friction*, *gravity*, *forces*, *magnetic*, and *interactions*. Students should be given opportunities in class to practice using these words in context. An example is being given a force diagram and placing the words in their correct locations in the diagram.

CA CCSS for ELA/Literacy Standards: RI.3.4; L.3.4, 5

CA ELD Standards: ELD.PI.3.1, 12

Patterns in Motion

Knowing that every change in motion requires a force, students can now consider much more complicated motions on the playground. When a ball gets thrown upward, what force causes it to come down? In a game of handball, students throw the ball against the wall and it bounces back. How do forces on the ball change from one moment to the next during the game?

Observing motion on the schoolyard, students begin to notice that there are certain patterns in the way objects move. Balls that go up always come down. In a game of handball, students throw a ball against the wall and can predict where it will end up. A basketball reflecting off a backboard follows a similar pattern. A tetherball spirals downward at the end of a game as it slows down. Noticing the **pattern [CCC-1]** allows students to predict the motion of the object (3-PS2-2). The clarification statement for 3-PS2-2 indicates that the focus of this investigation should be on motion that repeats periodically, like the back-and-forth movement of a child on a swing. This specificity is not arbitrary—noticing the repeating patterns in motion is a key precursor to studying wave motion in fourth grade. Students will build on that experience with waves as they move toward the middle grades and high school to study the engineering application of waves in modern technology.

Ideally, students can **investigate [SEP-3]** **patterns [CCC-1]** of motion on a school swing set and use their observations to make and test predictions (3-PS2-2). If one is not available, small classroom pendulums (such as a small metal washer tied to the end of a string) are **physical models [SEP-2]**. What happens when they pull the swing back from different distances? Can they predict how far forward or how high the swing will travel based on how far back they pull the swing initially? By observing the length of time it takes to do two back and forth cycles, can they predict how long it will take the swing to complete four cycles? Can they identify a relationship between how far back they pull the swing and how long it takes to complete a back and forth cycle? If they do have access to both a swing set and a classroom pendulum, can they use patterns that they spot in the model to predict what will happen in the real swing? Students can attempt to identify the different forces acting in the swing system that **cause [CCC-2]** the repeated motion, but a complete explanation is not appropriate for grade-three levels of understanding. Students should be able to recognize that there are forces on the swinging person that cause it to change motion. Teachers can recognize that the force of gravity always pulls on the object in the same direction (downward) with the same force. The fact that the motion is constantly changing means that there must be another force that is changing. In this case, that force comes from the chain. Because the chain is always changing angles, it acts in different directions at different moments—sometimes pulling in a direction that reinforces gravity and sometimes pulling at an angle that works against it. Other cyclic patterns to investigate could be balls bouncing multiple times when dropped from different heights or a weight bouncing up and down when attached to a rubber band hanging from the monkey bars. Like the swing, these include gravity pulling down and a restoring force caused by a spring-like elastic material in both these cases.

Opportunities for Mathematics Connections

During the investigation on forces, students may need to measure and weigh different objects. Some students will need experience using the measurement tools. For example, students need to know that the scale should be balanced or zeroed out before beginning the measurement; to use a ruler, the end of the object being measured must line up at the zero mark on the ruler, etc.

CA CCSSM: 3.OA.1–7, MP 5, 6

Forces Without Touching

While students can feel when they apply a push or pull to an object that they touch, some forces do not require any contact at all. Gravity, electric force (*static electricity*), and magnetic force are all invisible forces, but they can change the motion of objects in exactly the same way as pushes or pulls between objects that touch.

Grade Three Snapshot 4.2: Probing Students' Initial Ideas on Forces

Ms. M's class has been discussing the forces between objects when they push or pull against one another, but to start the unit, she wanted to see what their initial ideas were about forces that do not require objects to be touching. She began, "Please take out your lab notebooks because I have a challenge question to probe your thinking. I am going to read you a story about two students and ask you to choose which one you agree with more. As scientists, I want you to **support your choice with evidence [SEP-7]** or examples from your experiences." Ms. M read the prompt and gave her students a few minutes to record their initial thinking in their notebooks.

Probe: Does It Have to Touch?

Two friends were arguing about forces. They disagreed about whether something had to be touched for a force to act. This is what they said:

Akiko: "I think two things have to touch in order to have a force between them."

Fern: "I don't think two things have to touch in order to have a force between them."

Which friend do you agree with most? Explain or draw a picture of your thinking. Provide examples that support your ideas about forces.

From Keeley and Harrington 2010

Ms. M continued, "Now turn to your thinking partner and share your choice and your thinking… Remember to listen respectfully to each other even if you do not agree. You can change your answer or add more evidence to your notebook entry if your thinking changes." She let the thinking partners share while she walked around the room listening to discussions and helping students to remain on task.

Everyday phenomena: Some objects move only when you touch them while others move without being touched.

After ten minutes of animated discussion, Miss M returned to the front of the class, "So, let's see where we are as a group. When I say GO, you'll put one finger up if you agree most with Akiko and two fingers up if you agree most with Fern. Ready, set GO!" The group was evenly split.

She prompted students to find a partner who disagreed with them. After a few minutes of discussion, Ms. M initiated a whole-class discussion and recorded student ideas on the board. Supporters of Akiko's position pointed out evidence like "A soccer ball won't move unless I kick it" and "My book has to touch the table to have the table push on it." Supporters of Fern's position pointed out other evidence. Clara said "If I push a ball up in the air, it is going up but then it will fall down. Nothing is touching it, but it moves down. There's gravity even though the ball isn't touching the Earth." Aisha also explained excitedly, "Magnets push and pull even when they don't touch objects. My grandma has a magnet that I can use to make a paperclip move on top of the kitchen table by moving

Grade Three Snapshot 4.2: Probing Students' Initial Ideas on Forces

the magnet around **below** the table. It's like magic."

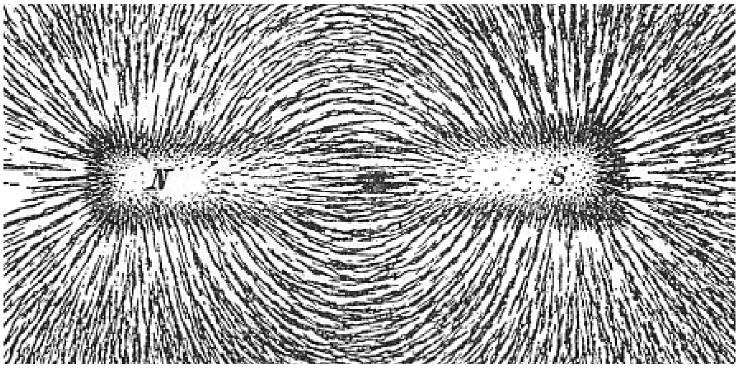
Ms. M then used her students' initial ideas to identify and introduce forces that can act without touching. She told students, "In the next weeks we will be learning more about interactions such as gravity, magnetism, and static electricity. At the end you will be able to explain how Aisha can magically move the paperclip with her grandmother's magnet."

Resources:

Keeley, Page, and Rand Harrington. 2010. *Uncovering Student Ideas in Physical Science: 45 New Force and Motion Assessment Probes.* Arlington: National Science Teachers Association.

Electric fields are easy to visualize with scraps of paper attracted to a charged balloon (rubbed against someone's hair), but the changes from static electricity are so small that it is hard to physically feel the force. Magnets, however, can be strong enough that students can physically feel their motion. When students have the opportunity to freely explore with different magnets and magnetic objects, they come up with all sorts of **questions [SEP-1]** about how they work. Teachers can help students focus on a few questions that could be investigated in the classroom about **cause and effect relationships [CCC-2]** (3-PS2-3). Questions might include the following: How do magnets affect different types of objects? How does the magnet's orientation change the magnet's effect on other magnets or objects? How does the distance between the magnet and the object affect the strength of the magnetic force? By sprinkling iron filings in a flat, sealable plastic container (for protection from getting into eyes, nose, or mouth) and holding the container above a magnet, students can ask questions about how the position of the magnet affects the pattern that the iron filings make (figure 4.3). In each of these example questions, the question includes a reference to both a cause and an effect. A question such as, What happens if I put three magnets together? is a great example of curiosity but it does not include any specific statement about the effect. After a student has the chance to try out this interesting question, the teacher can help the student ask the next level of question that includes both the cause and effect, such as, How does the number of magnets affect the strength of the magnetic force? Scientists often begin with open-ended curiosity-based questions but then need to convert those into questions that will later be used to design scientific investigations. Narrowing down both a cause and an effect will help determine what types of observations to collect, how to collect them, and what sort of data or measurements will be necessary to answer the question. Performance expectation 3-PS2-3 does not actually require that students perform any investigations or answer their questions, but students will probably want to anyway.

Figure 4.3. Iron Fillings in a Flat, Sealable Plastic Container



Source: Black and Davis 1913, 242, fig. 200
Long description of Figure 4.3.

Engineering Connection: Designing a Better Swing

Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. Some engineers design recreational equipment such as playground equipment. This engineering connection asks students to use magnets to make a "better" swing. This is one possible challenge in which students define a problem that could be solved by magnets (3-PS2-4). The emphasis in this performance expectation is on **defining the problem [SEP-1]**, which requires students to identify constraints and define the criteria for success (3–5-ETS1-1). Students can also generate multiple solutions and compare them (3–5-ETS1-2).

Prompt for students:
What if you could have a swing that made you go fast and high without any pushing or pulling by you or your friends? Can you figure out a way to use your understanding of magnets to design a swing that uses magnetic force to keep the swing moving? First, you need to figure out the requirements such as how big a person could ride the swing, how much space you have available on the playground for this new toy, and how many magnets you can use. Then, you'll need to decide how you will know if you have succeeded. Is it enough for the swing to go back and forth once? Or does it need to keep going multiple times? How many? How high does it need to go in order to be fun enough? Sketch two different designs in your notebook. What are the relative advantages and disadvantages of each?

Materials for each group: a 2-foot length of string, two ring or disc magnets, one binder clip, one classroom chair.

Source: Based on Egg Harbor Township STEM Committee. 2013. 3rd Grade Motion and Stability Unit. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link1

Sample Integration of Science and ELD Standards in the Classroom

Students have experimented with magnets and observed videos of various inventions that use magnets and electricity. They listen to a teacher read aloud from an informational text about cause and effect relationships of electrical and magnetic interactions between two objects and how inventors design solutions to problems by using these scientific principles (3-PS2-3, 3-PS2-4). At strategic points during the teacher read-aloud, students discuss, in pairs, open-ended, detailed questions designed to promote extended discourse (e.g., In what ways does a magnet affect a compass? How do we know? What changes would you make to X design to make it better?). The students have an opportunity to practice their response before sharing out to the class. The teacher supports the comprehension of students at the Emerging level of English proficiency by using diagrams labeled in both English and the students' home language to support the ideas in the text and by attending to the meanings of general academic terms (in addition to science-specific terms). Before reading, the teacher also makes sure to show short videos related to the topic in the two primary home languages of students in the classroom: English and Spanish.

CA ELD Standards: ELD.PI.3.5

Source: Lagunoff et al. 2015, 252–253

IS2

Grade Three Instructional Segment 2: Life Cycles for Survival

In kindergarten and grade two, students identified and investigated specific needs of plants and animals. In IS2 for grade three, students observe specific organisms to see different aspects of their growth and development, traits, and behaviors that help them survive. While this instructional segment introduces three seemingly unrelated concepts (organisms have life cycles, they inherit traits from parents, and they often live in groups), the central theme is that these features are all ways that help animals meet their needs for surviving, finding mates, and reproducing.

GRADE THREE INSTRUCTIONAL SEGMENT 2: LIFE CYCLES FOR SURVIVAL

Guiding Questions

- What is the advantage of having a complicated life cycle of growth and development?
- How do animals' life cycles help them survive?
- How similar are animals and plants to their siblings and their parents?
- How does being similar to parents help an animal survive?
- Why do some animals live alone while others live in large groups?

Performance Expectations

Students who demonstrate understanding can do the following:

3-LS1-1 Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death. [Clarification Statement: Changes organisms go through during their life form a pattern.] [*Assessment Boundary: Assessment of plant life cycles is limited to those of flowering plants. Assessment does not include details of human reproduction.*]

3-LS3-1. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms. [Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents or among siblings. Emphasis is on organisms other than humans.] [*Assessment Boundary: Assessment does not include genetic mechanisms of inheritance and prediction of traits. Assessment is limited to non-human examples.*]

3-LS4-2. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing. [Clarification Statement: Examples of cause and effect relationships could be plants that have larger thorns than other plants may be less likely to be eaten by predators and animals that have better camouflage coloration than other animals may be more likely to survive and therefore more likely to leave offspring.]

3-LS2-1. Construct an argument that some animals form groups that help members survive.

GRADE THREE INSTRUCTIONAL SEGMENT 2: LIFE CYCLES FOR SURVIVAL		
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:		
Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-4] Analyzing and Interpreting Data [SEP-5] Using Mathematics and Computational Thinking [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS1.B: Growth and Development of Organisms LS2.D: Social Interactions and Group Behavior LS3.A: Inheritance of Traits LS3.B: Variation of Traits	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-6] Structure and Function [CCC-7] Stability and Change
Highlighted California Environmental Principles and Concepts: **Principle I** The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services. **Principle II** The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies. **Principle III** Natural systems proceed through cycles that humans depend upon, benefit from and can alter. **Principle IV** The exchange of matter between natural systems and human societies affects the long-term functioning of both.		
CA CCSS Math Connections: 3.MD.4		
CA CCSS for ELA/Literacy Connections: RI.3.7; SL.3.1, 2, 3		
CA ELD Standards Connections: ELD.3.PI.9		

Human babies have all the same body parts as adults but are just smaller and cuter. Tiny baby spiders emerge from spider eggs and the babies look like miniature versions of their parents. Butterfly eggs, however, do not contain tiny butterflies but instead contain caterpillars that look almost nothing like their parents until they undergo major changes later in life. Most flowering plants do not directly grow tiny little plants with tiny roots, leaves, and stems that pop out like babies. They produce seeds instead. Why are there differences? Why doesn't a caterpillar just stay a caterpillar and lay eggs? Why do plants produce so many seeds (most of which will never grow) when they could just grow a few tiny plants instead? Students will not learn enough to fully answer many of these questions in grade three, but they can make observations and recognize patterns that build toward answers in later grades.

Students begin with direct observations of different organisms' life cycles. They can grow seeds (including vegetables in a garden or fast growing plants such as *Brassica rapa* in the classroom), hatch insect eggs (such as milkweed bug, butterfly, or ladybug) or raise frogs from tadpole eggs. As they observe and carefully notice the changes in the organism, students **develop a model [SEP 2]** for the growth and development of the organism's life cycle (3-LS1-1). This model will likely take the form of a pictorial model (a diagram) that illustrates each stage of the life cycle. Note the performance expectation requires that *students* be able to develop their own model, not simply be given a model and correlate their observations to the model. An example that does not meet this goal comes from a lesson plan packaged with a manufacturer's live eggs: it recommends that teachers read an informational text to introduce the eggs to students on day 1, and the text has a complete pictorial model of the animal's life cycle right on the cover and then walks students through every stage of the animal's life. Instead, students can sketch the organism at regular intervals in science notebooks, describe in words the **changes [CCC-7]** they notice since the previous observation, and **ask questions [SEP-1]** about what they see. After they have seen an entire life cycle, they should be the ones to decide how many stages the organism underwent and how to describe each stage.

While it is ideal that students observe at least one organism directly throughout its full life cycle in their classroom, 3-LS1-1 also requires that students observe **patterns [CCC-1]** common in the life cycles of different organisms (all organisms are born, grow and develop, reproduce, and die). To explore a wide range of organisms, students can use images from informational texts or videos. Ideally, these images are presented as a sequence of regular snapshots of the animal (daily, weekly, etc.) so that the exercise is a virtual **investigation [SEP 3]** during which students **analyze the image data [SEP-4]** to **develop a model [SEP-2]** rather than simply **obtain information [SEP-8]** about the organism's life cycle by reading about someone else's synthesis of the ideas. By having students work in groups to investigate different organisms, students can come together to **communicate [SEP-8]** their life cycle models and make **claims [SEP-7]** that different organisms share common stages in their life cycles that serve similar purposes.

While it is true that all species of plants and animals undergo birth, growth, reproduction, and death, the timing and details can be very different between species. Some weedy plants take only a few weeks to transition from germination to flowering while others, like fruit trees, take 10 years or more to begin reproduction. Why are there such big differences in the timing of life cycle events? Teachers can help guide students to think about how an organism's life cycle relates to its needs. Plants need space to grow, so a weed that reproduces quickly can be the first to occupy bare or disturbed soil before other plants (after a fire, at the edge of a construction site, etc.). Plants need water and sunlight, so large fruit trees may need years to develop the extensive **structures [CCC-6]** (deep roots and leaves) to gather enough of these resources to produce juicy and sugary fruits.

Organisms have life cycles with different stages because life cycles help them meet their needs. Butterflies and moths lay their eggs on plants that their babies can eat. Caterpillars can therefore spend all their time eating and growing and do not have to worry about finding food. As adults with wings, the focus shifts and butterflies and moths travel great distances to find a mate and locate another food source for their offspring to eat. In some species (including the largest moths from the family *Saturniidae*), the division of labor is so extreme that the adults do not eat anything at all before they die. Plants have life cycles with a similar **pattern [CCC-1]**. They stay in one place where they build up enough energy to reproduce, and then have evolved strategies to mate (pollination by wind or insect) and disperse their offspring to new locations (seed dispersal by wind or animal). Grade three students are not expected to be able to fully explain the relationship between life cycles and animal needs, but they should be able to use their knowledge from grades K–2 to **ask questions [SEP 1]** about how life cycles might help organisms meet their needs.

Sample Integration of Science and ELD Standards in the Classroom

Students have been studying the concept that organisms have unique and diverse life cycles but all have birth, growth, reproduction, and death in common (3-LS1-1). Their study has included research, investigations, and looking for patterns in various examples of life cycles. Students are ready to plan and deliver an oral presentation of their findings, using pictures or realia for a dramatic representation of assigned organisms as evidence to explain how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing (e.g., plants with thorns versus without; camouflage) (3-LS4-2). The teacher has modeled, with one example, some of the characteristics, and has built, with student input, a word wall with illustrations for student reference. The teacher lists clear goals for the presentations and discusses them with the students. As students work in their groups, they identify, in their text and visual resources, the patterns for the life cycle of their group's organism and use materials provided (e.g., cotton, yarn, colors, tape, cardboard, chart paper) to build, refine, and prepare their models of the life cycle to share with their peers. They compare their information with groups studying a similar organism, to discuss patterns that they find (e.g., birds have eggs ➔ chicks ➔ adult bird, and moth and butterfly [or all insects] have eggs ➔ larva [caterpillar stage] ➔ pupa ➔ adult insect). With teacher facilitation, students chart the emergent patterns and discuss which organisms have better chances of living, growing, and surviving.

Once the model of the life cycle is drawn/built, each group is ready to give its oral presentation. Peers listen and get insight on their peers' presentations and gain teacher and student feedback to refine their own.

CA ELD Standards: ELD.3.PI.9

Source: Lagunoff et al. 2015, 261–262

EP&C Connection: After each presentation, the teacher asks the class to identify a way that human activities might influence the survival reproduction of each organism (EP&C II).

In grade one, students made observations to support the claim that young plants and animals look similar (but not identical) to their parents (1-LS3-1). In grade three, they revisit the exact same task but must analyze and interpret specific data to support their claim (3-LS3-1). They also place the slight differences between parent and child into the larger context of variation between all the organisms of the same species.

Students can explore this variation in their classrooms by growing plants or insects under controlled conditions and comparing traits. For example, teachers can purchase seed stock from exceptionally tall and short plants (such as fast growing *Brassica rapa*), grow one generation and have students collect seeds from them. Students that plant seeds from the tall plant find that their plant is also tall and vice-versa. As students analyze their data, they should also ask questions about how these differences could help plants and animals meet their needs. Students should be able to apply their knowledge of plant needs to explain how different traits can help plants survive or reproduce (3-LS4-2). A taller plant can reach the sunlight above its neighbors, but a shorter plant is less likely to be blown over by the wind or broken by a passing animal. Plants with larger flowers might attract more pollinators and therefore reproduce more effectively. A jackrabbit, elephant, desert fox, or dog with larger ears might be able to stay cooler than one with smaller ears. Students will return to this concept in IS3.

Students can also collect data about one or two features within a family from pictures (e.g., appearance of multiple individuals) and tables or graphs (e.g., height of seedlings at a given age). Students could describe the colors and patterns in families of guinea pigs, the shape and size of ears in dogs or cats, or the variation of color on maize samples (corn on the cob). For animals, students should ideally see offspring pictured with both parents to emphasize that offspring include a mix of traits from both their biological parents. Each individual is a slightly different mix of traits, which explains why siblings can look different or why different plants from a single seed source grow to slightly different heights even when grown in identical conditions. The word *mix* is an age-appropriate term from everyday language that students will replace in later years; in the middle grades, students will be able to explain the mixing in terms of genetics. The CA NGSS are filled with situations like this where students use **patterns [CCC-1]** to uncover evidence of a **cause and effect relationship [CCC-2]** in elementary school but do not develop an explanation or model that accounts for these patterns until later grades. Teachers that might be concerned about teaching their students a nontechnical term can consider how this progression in vocabulary reflects the nature of science where ideas are subject to refinement and revision. The introduction of more precise terminology occurs in parallel with enhanced conceptual understanding. To explicitly emphasize the nature of science, teachers explicitly identify such nontechnical terms as placeholders that will be refined in later grades.

The clarification statement for PE 3-LS3-1 emphasizes organisms other than humans. If students bring up human traits, teachers must recognize that many of their students may not live with both biological parents or may not even know who both biological parents are. While only the biological parents contribute physical traits to a child, the adults who chose to be part of that child's life will heavily influence that child's personality and disposition.

Grade Three Snapshot 4.2: Graphing Variation

Anchoring phenomenon: Different caterpillars grow at different rates.

Ms. P's class observed the life cycle of the hornworm caterpillar (*Manduca sexta*). Pairs of students ensured that their caterpillar's needs were met by providing food, water, and keeping the plastic enclosure clean. Every few days, they **measured the length [SEP-5]** of their caterpillar. Ms. P called up each pair to mark the length of their caterpillar on the line plot for the day so that students could visualize this variation (CA CCSSM 3.MD.4). She posted the daily plots on the wall so that students could track how the caterpillars had grown over time. Even though the animals had access to the same food and lived in the same environment, some individuals grew bigger than others.

Investigative phenomenon: Caterpillars of the same type share many features in common but other features differ.

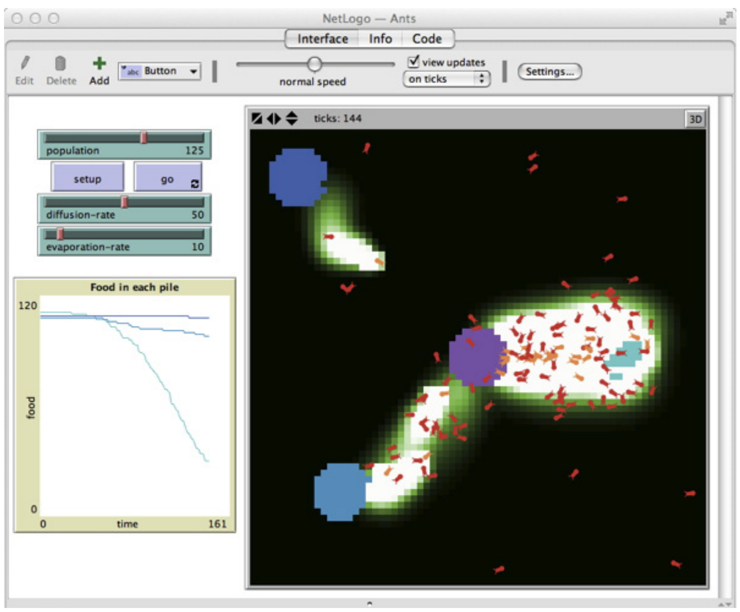
Ms. P focused student attention on the variation between caterpillars and had students **compare [SEP-4]** two caterpillars side-by-side, making a list of all the similarities and differences ("They both have seven stripes and nine spots. The spot sizes and shapes are slightly different"). Ms. P then showed students a picture of two caterpillars (including a ruler that reveals their lengths). She asked students which they think was more likely to be a baby picture of the mother of their caterpillar and what observations **support their claim [SEP-7]**.

Group Behaviors for Survival

Why do some animal families stick together in large groups while other animals live alone? In each case, animals behave the way they do to meet their needs, survive, and reproduce. When parents live separately from their young (or when the parent dies shortly after reproducing), children do not have to compete with their parents for resources. When animals live in groups, they can assist one another. Science experiences for third graders can include activities and games where teams complete tasks that highlight the potential individual benefits of cooperative behavior. It is often difficult to directly observe the benefits of group behavior of animals in the classroom, so students can investigate specific animal groups through informational literature and media such as groups of penguins in the arctic, zebras in Africa, schools of fish, or bird flocks. Humpback whales are particularly interesting California animals that are largely solitary, but travel in small groups during migration and occasionally cooperate in something called *bubble net feeding* when a group converges at a single location and comes to the surface in perfect unison to feast on schools of small fish (National Geographic 2014). With such clear demonstrations of their ability to collaborate, why do they usually live alone? How does that enable them to meet their needs and survive better?

Students can also indirectly observe group behavior through computer simulations like NetLogo (Wilensky 1999). These programs allow students to track individual organisms to see how they interact with others to meet their needs. In a simulation of an ant colony (figure 4.4), students can explore how the size of the ant colony affects the amount of food collected (including the success of a single ant) or what would happen if the colony were unable to communicate using pheromones. Students use this evidence to support an argument that the colony helps the ants survive (3-LS2-1).

Figure 4.4. Computer Simulation of Group Behavior in Ants



In this NetLogo computer simulation, ants (red) leave a trail of pheromones (white) that helps other ants find food (blue) around their nest (purple). *Source:* Wilensky 1999; Wilensky 1997
Long description of Figure 4.4.

IS3 Grade Three Instructional Segment 3: Surviving in Different Environments

While genetics plays an important role in shaping organisms, IS3 focuses on the organism's interaction with the environment. Every organism has its needs met by the surrounding environment, but not all organisms can survive in all environments. Some plants and animals have traits that allow them to survive better in a specific environment, which ties directly to the concepts of the variation in traits from IS2 and forms the foundation for understanding natural selection in later grades. At this level, students gather specific evidence of **cause and effect relationships [CCC-2]** where the environment affects which organisms survive (EP&C II). They draw on observations of both living organisms and fossils.

GRADE THREE INSTRUCTIONAL SEGMENT 3: SURVIVING IN DIFFERENT ENVIRONMENTS

Guiding Questions

- How does the environment affect living organisms?
- How do organisms' traits help them survive in different environments?
- What happens to organisms when the environment changes?

Performance Expectations

Students who demonstrate understanding can do the following:

3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment. [Clarification Statement: Examples of the environment affecting a trait could include normally tall plants grown with insufficient water are stunted, and a pet dog that is given too much food and little exercise may become overweight.]

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. [Clarification Statement: Examples of evidence could include needs and characteristics of the organisms and habitats involved. The organisms and their habitat make up a system in which the parts depend on each other.]

3-LS4-1. Analyze and interpret data from fossils to provide evidence of the organism and the environments in which they lived long ago. [Clarification Statement: Examples of data could include type, size, and distributions of fossil organisms. Examples of fossils and environments could include marine fossils found on dry land, tropical plant fossils found in Arctic areas, and fossils of extinct organisms.] [*Assessment Boundary: Assessment does not include identification of specific fossils or present plants and animals. Assessment is limited to major fossil types and relative ages.*]

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.* [Clarification Statement: Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.] [*Assessment Boundary: Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.*]

GRADE THREE INSTRUCTIONAL SEGMENT 3: SURVIVING IN DIFFERENT ENVIRONMENTS

3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-4] Analyzing and Interpreting Data [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS3.A: Inheritance of Traits LS3.B: Variation of Traits LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS4.A: Evidence of Common Ancestry and Diversity LS4.C: Adaptation LS4.D: Biodiversity and Humans ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-3] Scale, Proportion, and Quantity [CCC-4] Systems and System Models

Highlighted California Environmental Principles and Concepts:

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

CA CCSS Math Connections: MP.2, MP.5; 3.MD.3

CA CCSS for ELA/Literacy Connections: W.3.1, 7; RI.3.1, 3, 5, 7; SL.3.1

CA ELD Standards Connections: ELD.PI.3.1, 10, 11

Students are likely to have some prior knowledge that if they eat unhealthy food, they might become overweight even if their parents are very thin. Could the foods they eat also affect their height, even if their parents are both tall? Some traits seem to depend on what happens to us during our lives. Does the availability of food affect the traits of other plants and animals? Can human-caused changes to the environment affect the traits of plants and animals?

Students can explore what happens when the same type of plant grows in places that have different environmental conditions on their schoolyard. First they must find two plants in different locations that are the same type and make specific observations of the individual plants and their environments, measuring specific **quantities [CCC-3]** when possible (number of leaves or flowers, height, largest leaf size for plants, temperature for environment; students can even quantify the soil hardness by measuring how far a nail penetrates when hitting it three times with a hammer). How does each of the environmental conditions they describe affect the plant's ability to meet its needs? Teachers can focus on having students identify specific living and nonliving factors of the environment as well as human-caused changes (EP&C II), building on observations they made about habitats in grade two (2-LS4-1). Would they expect the plant to be more successful in one of the environments rather than the other (because its needs are met better there)? Based on their observations, is there evidence that one plant was growing more successfully than the other? While this activity motivates questions about the role of the environment in determining traits, students do not have enough information to **support an argument [SEP-7]** that the environment causes different growth rates. Maybe the differences in plant traits have a different **cause [CCC-2]**, like one plant being much older than the other or that the individual plants came from different parents with different traits. Teachers can explicitly emphasize the nature of science and discuss how investigations sometimes begin by making "imperfect" observations that lead to questions. Scientists then refine their **questions [SEP-1]** and make more systematic observations to answer them. Students should be ready to **plan such an investigation [SEP-3]**.

Opportunities for Mathematics Connections

Students can measure the effects of environment on the growth of seedlings. They **plan an investigation [SEP-3]** to **measure [CCC-3]** the **effect [CCC-2]** of one single nonliving factor in the environment on one single trait of a plant. They can simulate drought conditions, compare the growth in soil versus a *hydroponic* environment where the seed only has access to water, or vary the amount of sunlight hours per day. They measure the volume of water added (3.MD.2). As students make regular observations of each plant, they make numerical measurements of the height (3.MD.4) or number of leaves alongside descriptions and sketches. They should be able to report their findings as graphs (3.MD.3) and **explain [SEP-6]** how their observations are evidence of the DCI that environment can influence specific traits (3-LS3-2).

CA CCSSM: 3.MD.2-4, MP 2, 5

Thus far in grade three, students have developed a conceptual **model [SEP 2]** that both genetic inheritance and environmental factors, including human activities (EP&C II), affect traits (figure 4.5). There is an important difference between inherited traits and traits altered by the environment (*acquired traits*): only inherited traits are passed on to offspring. A mother whose skin is red from sunburn will not give birth to a sunburned baby. In an interesting demonstration of the nature of science, new discoveries in genetics are finding that there are some additional relationships between inherited traits and acquired traits where environmental conditions can deactivate certain genes in DNA. Understanding this new field of science, called *epigenetics*, is well beyond the third-grade level, but teachers should be aware that whenever scientists use labels to distinguish between categories (like inherited versus acquired traits), the distinction is often more complicated. Grade three teachers lay the groundwork by explicitly describing the scientific models as being subject to revision and refinement.

Figure 4.5. Conceptual Model of Factors that Affect Traits

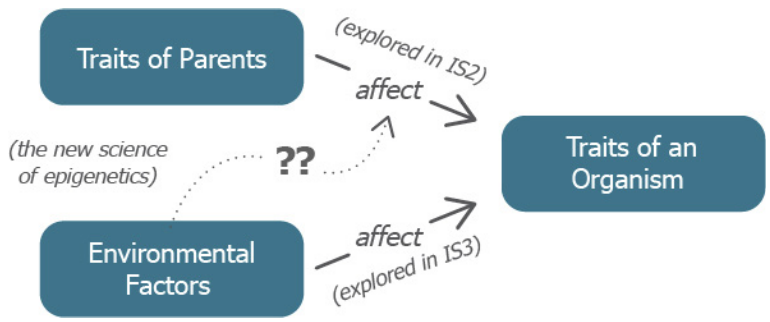
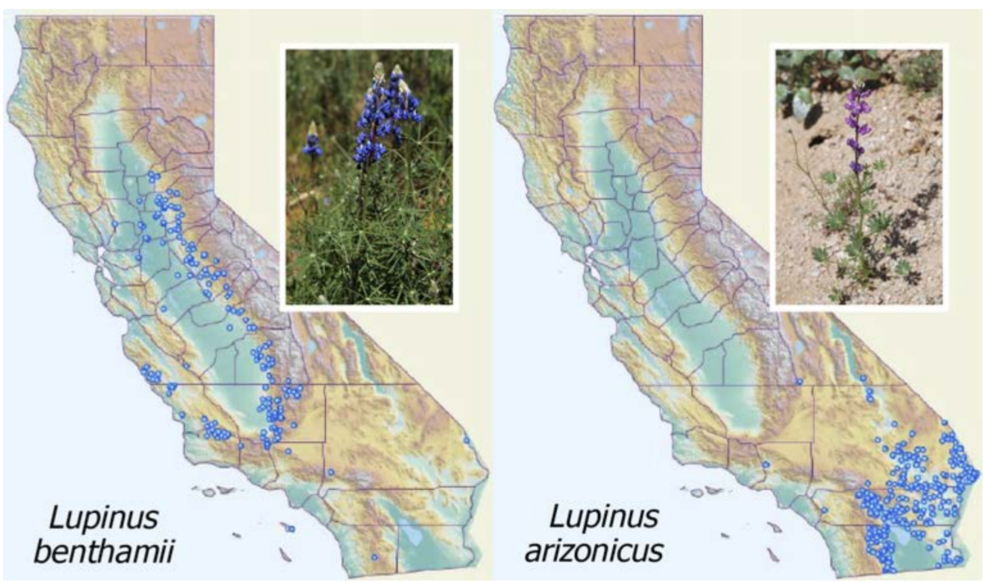


Diagram by M. d'Alessio
Long description of Figure 4.5.

In their investigations, students find that some environmental conditions are so poor that certain plants are not able to survive. In grade two, students observed a correlation, a **pattern [CCC-1]** that showed different levels of biodiversity in different habitats (2-LS4-1). Students extend this idea in grade three by **arguing [SEP-7]** that this pattern can be explained by a **cause and effect relationship [CCC-2]** between environmental conditions and survival. To construct this argument, they need evidence. Their experimental results are important pieces of evidence, but they also need to show that certain habitats have characteristics that match the needs of different organisms. Students can **obtain information [SEP-8]** about the different habitats in California and the needs of organisms that live within them. How do the traits of animals that live in the desert differ from those that live in the mountains? What special traits do marine plants and animals have that land organisms do not? Students could compare the growth of a California native salt marsh grass to turf grass in soils with different salt content. Students can gather evidence about the geographic distribution of specific organisms that show that not only do physical conditions affect survival of plants in the classroom, but they also have a real effect on where plants can survive in nature. Students can use online maps to identify patterns in where different species live throughout the state (California Education and the Environment Initiative 2013). A database of native plants such as lupines (Calflora 2016) reveal that some species live across many parts of California but only in certain narrow elevation ranges or bands along the coast, while others live in only an isolated region where very specific conditions enable its survival (figure 4.6). Examining the maps requires students to draw on their understanding of representations of landform shapes from grade two (2-ESS2-2). Students can describe how the traits of each plant differ in order to survive in these different conditions. Some databases even allow teachers to contribute photos and locations of plants and animals that they have observed in their local area so that students can be citizen scientists.

Figure 4.6. Snapshots from a Web Database of California Plants



Sources: Calflora 2015a; Christie 2002; Calflora 2015b; Andre 2011
Long description of Figure 4.6.

Interpreting Fossils

As an assessment of students' models of the relationship between organisms' traits and the locations where they live, students can play a matching game where they decide which different organisms are likely to live in which different environments. The assessment is not whether the student has identified an organism that actually lives in a specific setting, but rather that the student has **engaged in arguments from the evidence [SEP-7]** in the photos or information. This assessment sets the stage for introducing fossil evidence of past environments.

Fossils, usually found in layers of rock, are evidence of the existence of ancient life. Fossils preserve the shape of parts of ancient organisms' bodies that lived and died in the place where the fossil was found. The standard classroom activity where students create an impression of a plant or animal body part, gives students a tangible understanding of what a fossil is (or at least one type of fossil), but the emphasis in the CA NGSS is on the stories fossils tell about ancient environments and not simply on how a fossil forms. From the previous activities, students know that the shape and size of different parts of an organism depend upon the environmental conditions in which they live. Interpreting fossils is very much like the matching game assessment in the previous paragraph. The **structures [CCC-6]** of organisms preserved by fossils provide clues about the environmental conditions that were present when the fossil formed. Even if the fossilized organism is long extinct, it may show evidence of the same adaptations as those found in modern plants or animals. On the other hand, if students observe that a fossil at one location looks very different from the organisms that live in that spot today, they have evidence that the environment must have changed since the ancient organism was alive (3-LS4-1).

Urban examples that resemble fossils are imprints of leaves or footprints of a dog trapped in the concrete (U.S. Geological Survey [USGS] 2015b). Students can investigate imprints left in concrete surrounding the school, a local fossil, or pictures of fossils and come up with a story about what the local community may have been like when the modern-day fossil formed. In the case of a sidewalk impression, the environment has not changed much since the concrete dried (dogs still roam the neighborhood and the same tree may still be growing beside the sidewalk). The fossils that students can discover in California include some organisms that are very different from those that live here today. For example, the fossils of giant sea creatures are found in the hills and mountains around California, telling us that these pieces of land were once under water (e.g., Plesiosaur fossil found near Fresno). Teachers can obtain a list of fossils found in their county using an online database (University of California Museum of Paleontology n.d.) or have students explore more user-friendly online databases that may contain less detailed information (The Paleontology Portal n.d.). Then they can analyze a collection of fossils found in the same place to determine what the environment was like in the geologic past (3-LS4-1).

Predicting and Minimizing Human Impacts on Ecosystems

Fossils provide evidence that ecosystems can change over millions of years, but students can also predict the impact of shorter-term changes to ecosystems. By analyzing pictures or paintings of their local community from historical documents, students can describe how humans changed the environmental conditions when they developed the land (EP&C II). How have these changes influenced the organisms within the ecosystem? The key to answering this question lies in defining the different components of the **system [CCC-4]** and how they interact with one another, in this case focusing on the impacts of humans on local natural systems. Once they have this information students can predict how human-caused changes to the ecosystem will affect the plants and animals that live there.

Students can **investigate [SEP-3]** ecosystem interactions in real life by visiting the schoolyard, a local garden or park, or taking a field trip to an aquatic environment (stream, lake, river, or beach). If this is not possible, students can examine these interactions through literature and media, and simulations. They can ask questions about the living and nonliving components of the ecosystem such as what kinds of plants live there, how the plants adapted to the current conditions, where the water comes from, and what changes to the natural environment were made by humans. Students share their notes and place elements into a chart with human-made and natural components in the system. Students then read informational texts and gather evidence about how a natural habitat has changed as a result of one or more human activities (CA CCSS for ELA/Literacy RI.3.1; W.3.7). Teachers help students identify the types of environmental changes described in the text, including changes in land characteristics, water distribution, temperature, soil, and plant and animal life. How will these changes affect the rest of the ecosystem? Students select one of the described environmental changes and make a list of the series of events they think might have caused these changes, using language that pertains to time, sequence, **cause and effect [CCC-2]** (CA CCSS for ELA/Literacy RI.3.3.), and to EP&C II. Lastly, students can use computer simulations of ecosystems to directly manipulate the amount of resources such as water or space and see how populations react (grade three students should not be expected to create their own simulations). Using simulations like these give students the opportunity to test out different scenarios and instantly see the results. This will enhance their mental models of ecosystem changes. Students can then illustrate different cause and effect connections, including the results of human activities, they identify in the simulations using simple **pictorial models [SEP-2]** such as concept maps.

Grade Three Snapshot 4.4: Living Things in Changing Environments

Anchoring Phenomenon: Some places on the schoolyard have lots of plants and animals while other places have fewer.

Ms. J introduced her students to the idea of environmental changes (EP&C II) by taking her class on a field trip to visit the campus, surrounding neighborhood, and a local park. In preparation for this activity, Ms. J identified three areas near the school where her students could see plants and animals, and observe the effects of human activities; she also enlisted a parent volunteer to go along. Before going outside, Ms. J explained to the students that they would be going on a local field trip to make observations and collect evidence about environmental changes on campus and in the local neighborhood. She told them to bring pencils and their science journal so that they could make notes about their observations.

While walking around campus, the students observed and **asked questions [SEP-1]** about why there were very few plants and animals on the school grounds. Ms. J had them make notes about their observations and record any questions in their science notebooks during their **investigation [SEP-3]** of environmental changes in the local area. The class walked down the street, making observations and taking notes as they went by houses and apartment buildings in the neighborhood. They observed that some areas had green spaces with different kinds of plants and animals, and saw many birds sitting on the branches of the bushes and squirrels running through the yards. Finally, Ms. J took them to visit a local park where they saw even more plants and animals. As they walked back to the school, Ms. J kicked off a discussion by asking students if they observed any **patterns [CCC-1]** regarding the variety and numbers of plants and animals they observed in the three different areas.

Back in their classroom, Ms. J guided a student discussion of similarities and differences among the areas they visited during their field trip. She made a four-column list on the board labeled “Place,” “Description of Area,” “Plants We Saw,” and “Animals We Saw.” With their data recorded, Ms. J asked the students to contribute to a list of the differences in plants and animals among the three habitats: campus, neighborhood, and park. The class then began a discussion to **analyze and interpret [SEP-4]** the data they collected and began thinking about the **causes [CCC-2]** of these differences. Students identified several human activities, such as removing trees, making streets, paving the campus, and building houses. Once they completed their list, Ms. J asked students to identify the evidence they saw during their field trip that supports the **argument [SEP 7]** that changes in habitats affect the organisms living there. Some organisms can survive well, some survive less well, and some cannot survive at all. Ms. J recorded the students’ evidence on the board.

Grade Three Snapshot 4.4: Living Things in Changing Environments

Investigative phenomenon: Sweetwater Marsh is changing.

Ms. J recognized the importance of developing her students' awareness that environmental changes they observe locally also occur throughout California. She used the leveled reader *Sweetwater Marsh National Wildlife Refuge* as the basis for student investigations of how humans have changed a rapidly disappearing coastal habitat (EP&C II), which serves as a breeding ground and nursery for many of the fish that people eat (EP&C I).

Using information the students gathered from the reading, the class made a mural with "before" and "after" sections where some students drew the original habitat and others showed the habitat after human activity. The students' drawings illustrated some changes, for example, the addition of buildings, roads, and levees. This reading and mural served as the context for a discussion of how the functioning and health of ecosystems are influenced by their relationships with human societies.

To reinforce the crosscutting concept about **systems and system models [CCC-4]**, Ms. J reminded the students that ecosystems are an example of a system. She asked them to identify the salt marsh ecosystem components on their mural. Several students pointed out the birds nesting in the plants as an example of an interaction among the components of the ecosystem.

After completing their mural, Ms. J asked the students several questions about the marsh, its plants and animals, and how the habitat might change if more human-activity occurs there. She focused the students on environmental changes asking them to predict answers to questions such as, Which plants or animals will be affected if the water becomes saltier? and If the water in all of the San Diego Bay becomes muddier, what might happen? Based on their notes and the class discussion, students identified the main idea of the lesson: human activities had resulted in changes to the natural habitat, which in turn had decreased the number and variety of plants and animals in the area.

Resources

California Education and the Environment Initiative. 2013. *Sweetwater Marsh National Wildlife Refuge*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link2.

Through these activities, students enhance their understanding of the EP&Cs. They can identify direct and indirect changes to natural systems due to the growth of human populations and their consumption rates. Some communities may feel the impacts from resource extraction, harvest, transport or consumption. Other communities might be able to observe the effects of expansion and operation of human activities on the geographic extent, composition, biological diversity, and viability of natural systems. In the end, the focus should be on possible solutions that minimize the impacts of humans on the natural system.

Engineering Connection: Minimizing the Effects of a Levy Break on the Environment

Environmental changes happen all the time and are a part of natural cycles, but human activities can influence those cycles resulting in profound changes to the natural environment (EP&C III). Many ecosystems become unstable as a result of these changes (EP&C II). For example, before human development, animals could migrate out of an area affected by a wildfire into an adjacent area where they could survive. If the wildfire area is now adjacent to human development, there is no natural habitat left where the animals can move in order to survive. Recognizing these impacts, humans have come up with technologies and solutions to minimize the **effects [CCC-2]** of their activities on the environment or to help organisms respond to natural changes that they might previously been able to survive.

Students should **obtain information [SEP-8]** about a locally relevant environmental change (flood, wildfire, drought, new housing development, freeway expansion, etc.), ideally by observing an environmental change in their local community. Based on this information they should be able to **define the problem [SEP-1]**, identifying the changes that will happen in the environment and predicting their possible impacts on the ecosystem (3–5-ETS1-1). Using this information students can establish criteria for comparing solutions to the problem based on what they have learned about decision-making related to natural resources (EP&C V). Having established the criteria, they can begin to generate and compare multiple possible solutions to the problem, and evaluate the pros and cons of each (3–5-ETS1-1).

In one farming community near the Sacramento River, a teacher brings in a news article that warns the next flood might breach the levy and wash harmful pesticides from the fields into the river. Students predict that this will kill all the fish and they want to stop this. Different groups come up with different solutions. One group recommends that they strengthen the levy while another group suggests that they stop using the harmful chemicals on their crops. A third group suggests that they can develop a new technology to clean up the chemicals (“like a giant sponge”). In the end, students must make an argument in favor of one of the class’ solutions (3-LS4-4).

IS4

Grade Three Instructional Segment 4: Weather Impacts

Students build on their observations of weather patterns from kindergarten, this time focusing on describing these patterns **quantitatively [CCC-3]**. As in kindergarten, their observations begin locally, but the numbers and graphical representations allow them to compare weather patterns from different places across the world. Students also explore the impact of weather-related hazards on their local community and design solutions to minimize the impacts on humans.

GRADE THREE INSTRUCTIONAL SEGMENT 4: WEATHER IMPACTS

Guiding Questions

- What is typical weather in my local region?
- How does it compare to other areas of California and the world?
- What weather patterns are common for different seasons?
- What weather-related hazards are in my region?
- How can we reduce weather-related hazards?

Performance Expectations

Students who demonstrate understanding can do the following:

3-ESS2-1. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season. [Clarification Statement: Examples of data at this grade level could include average temperature, precipitation, and wind direction.] [*Assessment Boundary: Assessment of graphical displays is limited to pictographs and bar graphs. Assessment does not include climate change.*]

3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.* [Clarification Statement: Examples of design solutions to weather-related hazards could include barriers to prevent flooding, wind-resistant roofs, and lighting rods.]

3-ESS2-2. Obtain and combine information to describe climates in different regions of the world.

3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

GRADE THREE INSTRUCTIONAL SEGMENT 4: WEATHER IMPACTS

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-4] Analyzing and Interpreting Data [SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	ESS2.D Weather and Climate ESS3.B: Natural Hazards ETS1.B: Developing Possible Solutions	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-6] Structure and Function

Highlighted California Environmental Principles and Concepts:

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

CA CCSS Math Connections: MP.5; 3.MD.3, 4

CA CCSS for ELA/Literacy Connections: W3.1B, W3.8, SL.3.1, SL.3.2, SL.3.3, SL.3.4, RI.3.1, RI.3.3, RI.3.4, RI.3.5, RI.3.7

CA ELD Standards Connections: 3.P1.A.1, 3.P1.A.2, 3.P1.B.5, 3.P1.C.9

The grade three vignette on weather impacts illustrates a sample instructional sequence that fully prepares students to meet most of the performance expectations in this instructional segment. It illustrates how weather observations can be integrated into the curriculum throughout the year and then highlights how students can analyze their data and apply their findings during a focused unit of instruction late in the school year.

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

Performance Expectations

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3-ESS2-2. Obtain and combine information to describe climates in different regions of the world.

3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.* [Clarification Statement: Examples of design solutions to weather-related hazards could include barriers to prevent flooding, wind-resistant roofs, and lighting rods.]

3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-4] Analyzing and Interpreting Data [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-8] Obtaining, Evaluating, and Communicating Information	ESS2.D Weather and Climate ESS3.B: Natural Hazards ETS1.B: Developing Possible Solutions	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-6] Structure and Function

Highlighted California Environmental Principles and Concepts:

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Principle V Decisions affecting resources and natural systems are complex and involve many factors.

CA CCSS Math Connections: 3.MD.3, 3.MD.4

CA CCSS for ELA/Literacy Connections: W3.1a-b, W3.7, W3.8, SL.3.1, SL.3.2, SL.3.3, SL.3.4, RI.3.1, RI.3.3, RI.3.4, RI.3.5, RI.3.7

CA ELD Standards Connections: 3.P1.A.1, 3.P1.A.2, 3.P1.B.5, 3.P1.C.9

Introduction

This vignette illustrates ways that three-dimensional CA NGSS implementation can be aligned to support the development of environmental literacy and problem solving using the campus as a context for learning. It highlights ways that regular data collection and data analysis help scientists understand the natural world.

How does Weather Impact our Community?

Drawing from the social studies curriculum, Mr. C chose a yearlong theme of community. He worked to tie lessons back to the students' school, their homes, their neighborhood, and their city. Mr. C attempted to integrate science into the theme of community. This worked well for his life science unit about Ecosystems and Interdependence as students investigate local plant and animal communities and their interactions with humans. Mr. C's unit on weather depended on two activities that took place long before the unit began: students made a detailed site map of their schoolyard and collected regular daily weather measurements all year long. These two activities culminated in the spring when students analyzed the data they collected to identify patterns and weather related hazards that they could do something about.

Daily Weather Tracking

Anchor phenomenon: Weather conditions change each day over the course of the year.

Every day at the end of lunch, the students recorded the weather. Was it mostly sunny or cloudy? Windy? Rainy? Some days there was mixed weather, sunny and windy, for example. The class agreed to choose the main weather feature they observed on any mixed weather days. Based on each day's weather report, a student placed a different color dot on the large calendar section of a weather bulletin board Mr. C had created for the school year—yellow for sunny, grey for cloudy, blue for rainy, green for windy, white for foggy, etc. Mr. C taught students to read an outdoor thermometer just outside of the classroom; each week, a different pair of students took turns reading the daily end-of-lunch temperature and recording the data on the calendar. If the temperature was warmer than the day before, students recorded the new temperature in red ink; they used blue ink if it was cooler, and black ink if

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

the temperature was the same as the previous day. By the end of the first month of school, the activity became routine and took only a minute or two after lunch recess.

Schoolyard Site Map

Investigative phenomenon: Features like the flow of water, the growth of plants and animals, and the wind patterns all varied by location on the schoolyard.

As part of the yearlong theme of "Community," students created a "Schoolyard Survey Map." They mapped the natural and built features of the campus, identified different ways that various areas of campus were used, noted environmental features like sunny and shady areas of campus, the direction of prevailing winds, and any visible signs of water runoff. Mr. C asked students to record where living things like plants and animals were located and indicated the ways that children used each area of the schoolyard. Students made their own maps and then Mr. C facilitated a class process to compile a larger version of the campus map that remained a key part of his bulletin board all year long. Students referred to their maps whenever interesting events occurred on campus.

Teachable Moments about Interesting Weather Events (Engage)

Investigative phenomenon: The temperature suddenly jumped 10°F in one day.

Occasionally, there was an interesting weather event— a day where the weather changed, or a day that was particularly hot or cold. Mr. C planned for these days by monitoring the weather forecasts and used these phenomena to drive class investigations and discussion. In late September, the temperature suddenly jumped 10 degrees Fahrenheit compared to the previous day. Mr. C asked the class to generate **questions [SEP-1]** about the weather and the impact it had on them. Students wondered: Why is it so hot today? Why am I so sweaty? What's the hottest it's ever been on this day? Where is the hottest place in the world? Using a class set of laptops, students worked individually to quickly try to find answers to these questions. Mr. C asked them to **evaluate the information sources [SEP-8]**: Which Web sites had the best answers to our questions? Which were easiest to use? How do we know if the Web sites are correct? Mr. C also asked, How did the weather affect your day? Students reported that the slide was too hot to use, but that it was really nice to lie down on the grass in the shade. By the end of the day, students answered the questions about the weather, listed ways that it affected their day, and also started bookmarking the most useful Internet sites for finding weather related data. Mr. C added a section to the bottom of the weather bulletin board for "Weather Events" and posted a piece of paper with notes about their hot weather day organized into three sections: "Local Facts" "Effects on People" and "Global Context." Mr. C added red post-it notes to the campus map noting the places where the heat made it difficult to do ordinary activities, that the slide was too hot to use, and that the blacktop was too hot and smelled funny.

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LOCAL FACTS	EFFECTS ON PEOPLE	GLOBAL CONTEXT
• It was 85°F today, 10° hotter than yesterday. • The hottest ever in our city on this day was 91°F in 2010. • The news said they would have a cooling center set up at the public library.	• The slide was too hot to use. • The blacktop made a smell. • I was sweaty. • I felt tired.	• The hottest temperature ever on Earth was 134°F in Death Valley, California on July 10, 2013. • Plants in hot climates have smaller leaves to deal with the heat. • Some big cities get extra hot because all the blacktop makes a heat island.

Over the course of the year, Mr. C worked with the students to make plans so they could find quick answers to questions about rain, wind, fog, dew, and by the end of January they had observed each of these phenomena. On March 3, the class was surprised by thunderstorms with hail, leading to a quick investigation and discussion of this unanticipated weather event. By the beginning of April, the class had recorded weather data on the chart for 130 school days, along with notes about the effects of heat, cold, wind, rain, fog, dew, and hail on campus activities. The lesson sequence below describes three weeks in April leading up to Earth Day.

Days 1–3: Looking for Patterns

Students analyzed the data they had collected throughout the school year and produced reports summarizing the weather in each month of the school year.

Day 4: Identifying Seasons

Students used their observations to describe the major characteristics of the four seasons. Using their data, they then made a claim about when each season "begins" and "ends."

Days 5–6: Which Hazards Affect Our School?

Students identified hazards that affected their school and then engaged in an argument about which hazards were most dangerous and significant at their school.

Day 7: Defining the Problem

Students researched places around the world that experience similar weather problems and found how those communities solve similar problems. Then students returned to the problem they faced at their own school and decided what their overall goal would be. They figured what they would be allowed to change and what was off limits.

Days 8–11: Designing Solutions

Students brainstormed criteria by which they would compare possible solutions; developed a variety of possible solutions; drew diagrams of one solution; shared their diagrams with other students; used their criteria to choose among the solutions; and completed a final design.

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Days 12–14: Final Presentations

Students communicated their design ideas to a group of decision-makers at their school during a formal presentation.

Days 1–3: Looking for Patterns (Explore)

Investigative phenomenon: Some months were particularly foggy while others were particularly sunny.

Even though students had been thinking about the data as they collected it throughout the year, starting in April they began to **analyze all the data [SEP 4]**. Some analysis required **mathematical thinking [SEP-5]** as they compared temperatures and counted days with particular weather features. Whether quantitative or not, students looked for **patterns [CCC-1]** in their weather data. Mr. C led a class discussion, asking students to look for groupings of weather patterns on the chart. Which months were particularly sunny? Which months were foggy? When did temperatures increase or decrease? When did it rain? Next, students identified the most common and most unusual weather events, including the hottest and coolest lunchtime temperatures in the previous seven months. Students found that the days were mostly sunny or foggy with a few rainy days. The most unusual event was the hail on March 3, but other events stood out too, like the five days in a row of heavy rain in January; the strong winds on March 1, 2, and 3 that broke branches on the tree in front of the school; and the day in October when the temperature was over 100 degrees.

Mr. C organized the class into seven groups and each group prepared a report for its assigned month following a template (3-ESS2-1). Each report included a pictograph showing how many days of each weather type were experienced in their assigned month, highest and lowest lunch time temperatures, and answers to the following questions: What was the most common type of weather this month? What were the most unusual weather events this month? What are three ways the weather was beneficial to people this month? What are three ways the weather might have been hazardous to people this month?

Day 4: Identifying Seasons (Explain)

When all the reports were complete, Mr. C lined them up in order on the board at the front of the class. He writes “Fall Equinox—September 22” above the September report, “Winter Solstice—December 21” above the December report and “Spring Equinox—March 20” above the March report. He explained that the fall equinox marks the end of summer and the beginning of fall; that the winter solstice marks the transition from fall to winter; and the spring equinox marks the end of winter and the beginning of spring. He noted that students will learn more about the solstices and equinoxes when they get to the middle grades, but for now, they just need to know that they mark the change of seasons. Working in pairs, students listed key features of each season on a graphic organizer with four quadrants. Then, they reviewed the monthly summaries and the day-to-day records from throughout the year to determine if they they agreed or

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

disagreed with the official starting dates for each season. Mr. C drew a timeline above the reports on the board and had each pair of students mark the date they believed each season began and ended. As students marked their dates on the board, students naturally engaged in an **argument from evidence [SEP 7]** by justifying their choices. Mr. C facilitated this discussion with *talk moves* (for an explanation, see chapter 11 on instructional strategies in this framework), prompting students with phrases like, "Tell me more about why you disagree with September 20…" or, "I know you marked December 12, but why do you think that the other group marked January 9?" There was broad agreement that summer weather lasted well into October noting the week with 100-degree temperatures and most groups argued that fall weather did not really start until Halloween when it was too cold and rainy for trick-or-treating. It was difficult for the class to agree on the start date for winter weather. Some students argued that winter started when there were five days of rain in a row in January, but other groups countered that the weather was actually warmer that week than it had been the entire month of December. Mr. C ended the class with a discussion during which students shared their observations about the characteristics of each season and the ways that weather could benefit or harm people.

Days 5–6: Which Hazards Affect Our School? (Explain/Elaborate)

Everyday phenomenon: The school faces certain hazards caused by weather conditions.

Mr. C introduced their next weather project: students would identify the most serious weather-related hazards on campus and design ways to reduce their effects on people, structures, and plants and animals found on the campus. On Earth Day, students would present their designs to the School Site Council as recommendations for improving the health and safety of the campus. He explained that a hazard is a "threat to life, health, property, or the environment" and used the campus map to point out some of the ways that weather events affected student activities during the school year. In groups, students filled in a chart listing common weather phenomena and the potential **effects [CCC-2]** on people, animals, plants, and structures on campus. Before lunch, Mr. C gave the students the assignment of finding a teacher or fifth grader on campus to ask about the most extreme weather events they had ever experienced at school. After lunch, students logged on to the class set of laptops and **obtained information [SEP-8]** from news articles about the most extreme weather events in their community in the last ten years. As the last task of the day, students constructed a written **argument [SEP-7]** responding to the prompt: Identify the top three types of weather events that present hazards on campus and in the local community. What evidence do you have that these types of weather are likely to create hazards on campus?

The next day, working in table groups, students shared their claims about hazardous weather events. Mr. C asked each table to come to a consensus listing the top three types of weather that impact their campus. Most table groups agreed that extremely hot days and very rainy days posed significant hazards. Hot slides burned their skin and sometimes it felt difficult to breathe when they were playing on the blacktop; rainy fields were muddy and slippery

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

leading to falls and on really rainy days, streams of water flood off the blacktop washing litter into the gutter and into storm drains. They also noted that both sunny and rainy days were relatively common throughout the school year. There was broad agreement about the top two most significant weather events, but there was disagreement about the third. Many students argued that wind was a problem, noting the time that tree branches came crashing down across the street from the school. Others claimed that dewy/foggy days were hazardous because of limited visibility and slippery ramps and stairs on campus. Several claimed that hail was a significant hazard because it could damage windows, cars, and plants on campus. Many groups seemed to be at an impasse, unable to come to consensus. Mr. C intervened and reminded the entire class that the main goal of this project was to design solutions to weather related hazards, so they might consider which hazards they thought they could do something about. By lunch, every table group reached consensus.

After lunch, Mr. C had each table group report on their discussion and the weather event on which they decided to focus, probing them to describe the **arguments and evidence [SEP-7]** that ended up tipping the group to a consensus. All the table groups listed heat and rain as two of their top three weather types, and there was a nearly even split between wind and hail among table groups as the third type of weather that generated significant hazards.

Before the class ended, Mr. C explained that students would work in teams to design solutions to weather-related hazards. He mentioned that there would be eight teams, two each for heat, rain, wind, and hail. Within each team, students would design solutions to hazards faced on campus. He asked students to list the top two weather types they were interested in addressing and also their top two choices for the group they want to protect: people, buildings, objects, or plants and animals.

Day 7: Defining the Problem (Elaborate)

Everyday problem: How do we reduce the impact of weather hazards?

Keeping student preferences in mind, Mr. C created eight *impact groups* of four to five students, two teams for each weather event (heat, rain, wind, and hail). Each impact group **obtained additional information [SEP-8]** about their weather event and identified the hazards it could create. Then, each impact group **obtained information [SEP-8]** about areas of the planet where their weather hazards were more common to see how people around the world work to reduce weather-related risks (3-ESS2-2). The groups then had to **define the problem [SEP-1]** they were trying to solve by

- identifying their weather event and the potential hazards they were hoping to minimize or prevent;
- defining the criteria they would use to select among their possible solutions;
- describing how they would measure whether or not their design succeeded or failed; and,
- identifying things that they realistically thought they would be allowed to change and what things would not be possible.

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

Days 8–11: Designing Solutions (Elaborate / Evaluate)

Next, each impact group identified one hazard related to their weather event that they wanted to address and began brainstorming ways to solve it. Over the course of a week, Mr. C dedicated at least an hour a day for group work to **develop solutions [SEP-6]**. By the end of the week, each impact group completed a labeled diagram of a design to reduce hazards on campus, which served as a **pictorial model [SEP-2]** of how the **structure of their design solution would help accomplish a specific function [CCC-6]**. One impact group proposed a shade structure over the slide to keep it cool on sunny days, another impact group designed a bio-swale to keep litter out of the storm drain to protect animals, a third impact group imagined a wind fence around the garden and planned to tie every flower to a stake to protect it from the wind.

Mr. C convened both impact groups that worked on the same weather event to share the hazards that they identified and discuss the possible effects of their hazard on people, structures, plants, and/or animals. Each team then identified the engineering solution they developed to minimize or avoid the hazard and gives the other group feedback using a "+/-/delta" protocol to identify the strengths and weaknesses they saw in each other's designs while also offering suggestions for improvements (3–5-ETS1-2). The impact groups made effective engineering **arguments [SEP-7]** based on their team discussions.

Each of the impact groups made a brief presentation about its hazard and engineering design solution. Mr. C told the students that they could comment on each other's solutions, especially as they related to the hazards that they worked on. For example, the wind impact group mentioned that they were worried that the shade structure proposed by the heat impact group might blow away in a heavy wind. They suggested that the heat impact group cement it deep into the ground. Based on feedback from this session, Mr. C asked students to refine and improve their designs. Students created new diagrams or other representations of their proposed solutions.

Days 12–14: Final Presentations (Evaluate)

Students next prepared for their presentation to the School Site Council, a group of parents, teachers, and the principal that makes decisions about the school campus. Each impact group had six minutes to share its design for reducing a weather related hazard on campus, meaning that each impact group gets just two minutes to **communicate [SEP-8]** how its design would reduce the effects of their hazard. Mr. C told them that the adults were excited to hear about the students' ideas for improving the campus, but there was no guarantee that they would adopt any of their suggestions. He told the students that many factors go into these important decisions (EP&C V). Mr. C provided a template presentation that ensured students clearly defined their hazard, presented evidence that the hazard existed on campus, and backed up their claim that their design would reduce the hazard (3-ESS3-1). He then provided class time for students to practice and get feedback to improve their presentations.

On Earth Day, students dressed up for their presentations to the School Site Council. Each impact group presented its design idea and asked the council to implement it before the next

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

school year. At the end of the day, Mr. C hosted a small celebration of students' efforts, presenting each impact group with a "Keepers of the Earth" certificate he designed for them. Mr. C was very proud of the students' efforts and hoped that the council would support at least one of their proposals. The next week the School Site Council announced that they had allocated funds to build a shade structure over the slide to keep it cool on sunny days. While most students were happy that an idea from their class was adopted, a few were disappointed that their own ideas were not selected. Attuned to this disappointment, Mr. C obtained permission for students to implement three other designs on their own. Later in the year, the class worked together to build a wind fence around the garden, to plant trees near the black top to provide shade and block the wind, and to build an insect habitat to protect insects from hail.

Vignette Debrief

SEPs. On days 1–4, students **analyzed their weather data [SEP-4]** looking for **trends and patterns [CCC-1]**. On day 4, Mr. C provided students an opportunity to engage in an **argument using evidence [SEP-7]** when they considered when each season began and ended. The argument was an authentic scientific discussion because there is no obvious correct answer. Instead, any answer that can be justified by the data is valid. When scientists make new discoveries, these sorts of discussions with other scientists may be the only way that they can verify their discoveries. On day 14, students engaged in a different kind of authentic **argument [SEP-7]** as part of their final presentations. In this case, they were trying to convince decision-makers that their engineering design was an effective solution to a problem.

Days 5–14 included portions of the engineering design process. While students **defined the problem [SEP-1]** on day 5, **developed solutions [SEP 6]** on days 6–8, and optimized their solutions during day 8, they never actually built, tested, or improved their designs using the results of scientific tests. In this case, the process of optimizing their engineering designs was limited to peer review of the initial designs. This example illustrated how effective engineering lessons could focus on parts of the engineering design cycle and did not need to encompass the entire cycle to be successful.

DCIs. On days 1–4, students focused on weather and climate (ESS2.D). Students noticed weather patterns in kindergarten, but in grade three they advance to recording the patterns and using them to predict future weather. They also generalized these patterns into a statement about an area's climate. (See appendix 1 for the progression). The second half of the lesson sequence related the natural weather processes to humans as one example of a natural hazard (ESS3.B). Students recognized that they could not stop the natural process but they could take steps to minimize its impact on people.

CCCs. Days 1–4 of the vignette had a strong focus on **data analysis [SEP-4]** during which students identified **patterns [CCC-1]** in a long series of weather data they collected themselves. Mr. C did not stop when students had identified the pattern, rather he asked them to interpret the patterns in terms of the four seasons, and then asked them to return to the specific data and see how well it matched up with the general pattern they had observed.

GRADE THREE VIGNETTE 4.1: HOW DOES WEATHER IMPACT MY COMMUNITY?

This cycle reflected a common theme in science when scientists move fluidly back and forth between data and generalizations. Scientists often use data to make generalizations, but anomalies (situations where specific data contradict the general pattern) can often lead to new discoveries or refinements to scientific models. In this third-grade lesson, students were only expected to recognize and describe patterns because they were not able to gather sufficient data to explain what caused the patterns.

EP&Cs. A major theme of these lessons was the interplay between natural weather phenomena and their impacts on people (EP&C II). Mr. C emphasized these relationships on each of the interesting weather days throughout the school year, and they worked to minimize these impacts during the design challenge starting on day 5. Several of the impact groups focused on the direct impacts on people and buildings/things that people created). Another impact group focused on the impacts of weather on the natural environment and how humans could diminish these impacts (EP&C III). Since these projects related to weather, a number of the solutions might alter the flow of water (EP&Cs II, IV). Teachers can emphasize these environmental connections both to the relevant impact groups and during whole class discussions.

CA CCSS Connections to English Language Arts and Mathematics: Throughout the lesson sequence, students researched weather patterns. They evaluated which Web sites provided the most accurate information. The students developed written arguments in groups about the top three weather hazards on their campus and provided evidence to support their arguments. They also developed and delivered a presentation to the School Site Council with design solutions to mitigate the weather hazards. Throughout the lesson sequence, students were recording weather data. They analyzed the data to identify weather patterns and anomalies.

This vignette was written by Mena Parmar and Nate Ivy of the Alameda County Office of Education.

Resources:

U.S. Fish and Wildlife Service. 2016. “Create a Schoolyard Site Survey Map.” In *2016 Living Schoolyard Activity* Guide—California Edition, edited by Sharon Danks. Green Schoolyards. America. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link3

The performance expectations 3-ESS2-1 and 3-ESS2-2 use two synonymous terms to discuss the same concept: “typical weather conditions during a particular season” and *climate*. Seeing these terms, teachers can realize the usefulness of the shorthand label of climate, but rather than frontloading the term climate at the beginning of the instructional segment or year, teachers can introduce it after students have collected the years’ worth of weather data and begun to recognize patterns in their observations. The difference between the terms *weather* and *climate* is that weather is the *actual* conditions at a specific time and place whereas climate refers to the *typical* conditions that can be expected in a given location at a particular time or season. While the actual conditions of the atmosphere change all the time (*weather*), there are certain typical weather patterns that repeat each day or each year at each location on Earth. For example, it almost never snows in San Francisco or Los Angeles, but it does snow every year in the mountains near Lake Tahoe and Big Bear, short drives from those cities. Snow usually only comes during the winter season in California's mountains, but other places on Earth, like Antarctica, receive snow year-round. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. Grade three students do not yet have the foundation to understand these processes. Instead, they **analyze and interpret [SEP-4]** **data tables and graphs [SEP-5]** to compare the climate in different cities. First students must learn to **obtain climate information [SEP-8]** from Web sites. Then they can demonstrate their ability to **evaluate and compare climate information [SEP-8]** from different regions, by creating travel brochures or packing lists for travel to different locations around the globe (3-ESS2-2).

Opportunities for Mathematics Connections

Students can construct a simple climatograph, a standard chart that combines a bar showing monthly precipitation with a line graph of average temperatures. Every student can create a climatograph for a different city or region and then place it on the wall beside a picture of habitat commonly found in that region. Then, they can compare cities. How much more rain falls in the rainforest of Brazil than the desert of Southern California? How much hotter is it in Sacramento than San Francisco during June?

CA CCSSM: 3.MD.3, 4; MP.5

Teachers should emphasize the connection that climate is one of the physical factors in an environment that determines the types of plants and animals that live in a particular region (California's History–Social Science standards call upon students to learn about the ecosystems near where they live). Students can compare climate information to information about different habitats, including looking at the global distribution of biomes. *Playing the Same Role* by the California Education and the Environment Initiative (see https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link4) includes extensive resources that students can use to examine the interconnections between climate and the distribution of Earth's biomes. Students might notice important **patterns [CCC 1]** such as the banding of specific biomes at different latitudes and differences between the biomes along the coast versus the interior of some continents (including distinct bands along the coast). Each of these **patterns [CCC 1]** is evidence of specific phenomena, though students should not be expected to construct explanations of what causes these patterns until the middle grades (MS-ESS2-6) (figure 4.7). They should be able to **ask questions [SEP 1]** about whether or not areas with similar biomes also have similar climate conditions and then **investigate [SEP-3]** using their climate data to find the answers.

Figure 4.7. Climate Affects Ecosystems

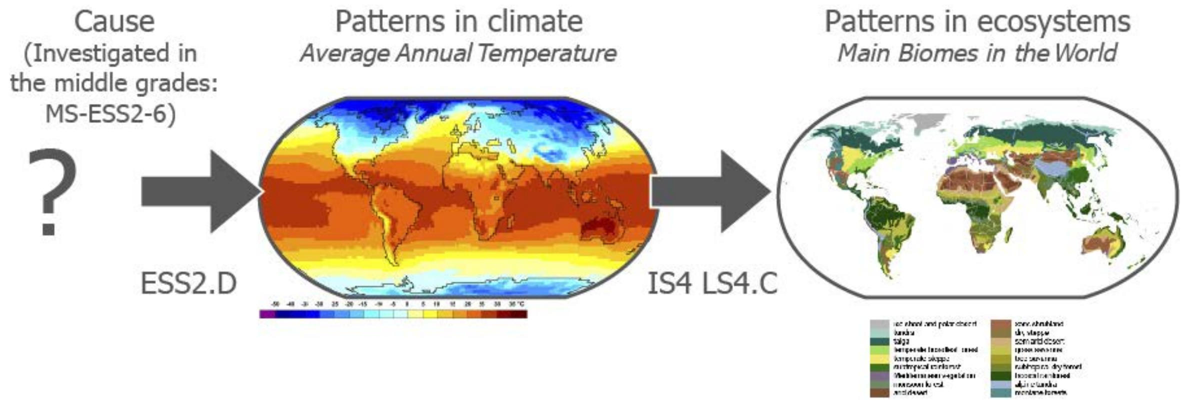


Illustration by M. d'Alessio with images from Department of Geography, University of Oregon 2000[1] and Koistinen 2007.
Long description of Figure 4.7.

The CA NGSS emphasize students' ability to describe the differences between the climate characteristics of the different locations on Earth. However, they do not require that students know the names of any of Earth's biomes. A focus on such terminology could distract from the real goal of honing students' ability to make observations, recognize **patterns [CCC-1]** in those observations, **ask questions [SEP-1]** about what might be **causing [CCC-2]** them, and then **engage in arguments from evidence [SEP-7]**.

Opportunities for ELA/ELD Connections

For additional background information from different sources that addresses weather and climate issues, students can investigate the Climate Kids, NASA's Eye on the Earth Web site, https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link6

Students can also compare important points and details from different informational texts, such as *Climates* by Theresa Alberti, *The Magic School Bus and the Climate Challenge* by Joanna Cole, and *Climate Maps* by Ian F. Mahaney.

CA CCSS for ELA/Literacy Standards: RI.3.3, 7, 9, W.3.10
CA ELD Standards: ELD.PI.3.6, 11

1. The source of this material is the COMET® Web site at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link5 of the University Corporation for Atmospheric Research (UCAR), sponsored in part through cooperative agreement(s) with the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (DOC). ©1997-2016 University Corporation for Atmospheric Research. All Rights Reserved.

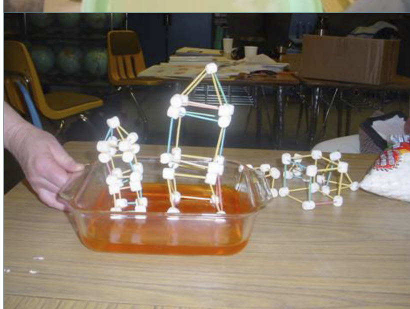
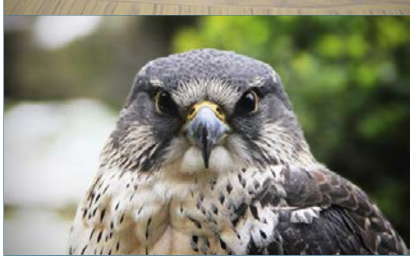
Grade Four

In the primary grades, students developed some simple models that identified the existence of cause and effect relationships for landscape changes, motion, and vision. What mechanisms drive these cause and effect relationships? Grade four students focus on both tangible processes like the erosion of soil and, for the first time, develop abstract concepts like energy. They also seek to explain some processes that are not directly observable such as internal body systems. Table 4.2 shows a sequence of five possible phenomenon-based instructional segments in grade four.

The tool chest of science and engineering practices (SEPs) expands in grade four. Students are able to use more sophisticated measurements and representations of data and then analyze it more thoughtfully. They are also able to construct more complicated pictorial models such as tracing the path of light rays as they reflect off objects. In grade four, students have the geometric reasoning skills to describe and measure angles.

Despite all their growing skills and knowledge, grade four students are still elementary children passionate about discovery and adventure. Teachers should capitalize on this energy by providing opportunities to play with cars or marbles crashing together, build towers, make up secret codes, go outside so that they can collect and observe insects, and play in the sand with stream tables. These concrete experiences allow students to connect their everyday experience to the abstract ideas that they are beginning to master.

Table 4.2. Overview of Instructional Segments for Grade Four

	**1 Car Crashes** Students investigate the energy of motion and how it transfers during collisions. They ask questions about the factors that affect energy changes during collisions.
	**2 Renewable Energy** Students investigate different devices that convert energy from one form to another and then design their own device. They obtain information about how we convert natural resources into usable energy and the environmental impacts of doing so.
	**3 Sculpting Landscapes** Students develop models of how sedimentary rocks form and use them to interpret the history of changes in the physical landscape. They perform investigations of the agents that erode and change landscapes.
	**4 Earthquake Engineering** Students explore earthquakes from three different perspectives: They use maps to identify patterns about where earthquakes occur on Earth, they develop models that describe waves and apply them to understanding earthquake shaking, and they design earthquake-resistant structures to withstand that shaking.
	**5 Animal Senses** Students develop a model of how animals see that includes their external body structures, internal body systems, and light, and information processing.

Sources: Duran Ortiz 2011; Leaflet 2004; M. d'Alessio; Figure 1 at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link7. Montani 2015

IS1 Grade Four Instructional Segment 1: Car Crashes

In earlier grades, students developed models for how objects push or pull against one another, but grade four is the first time that students encounter the abstract concept of energy and the flow of energy within systems. In IS1, students explore energy transfer in a visual, tangible form: collisions.

GRADE FOUR INSTRUCTIONAL SEGMENT 1: CAR CRASHES

Guiding Questions

- Why do car crashes cause so much damage?
- What happens to energy when objects collide?

Performance Expectations

Students who demonstrate understanding can do the following:

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object. [Clarification Statement: **Examples of evidence relating speed and energy could include change of shape on impact or other results of collisions (CA).**] [*Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.*]

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide. [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

California clarification statements that are bolded and followed by **CA** *were incorporated by the California Science Expert Review Panel.*

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and System Models [CCC-5] Energy and Matter: Flows, Cycles, and Conservation

CA CCSS for ELA/Literacy Connections: RI.4.1, 3, 9; W.4.2 a–d, 7, 8, 9 a–b

CA ELD Standards Connections: ELD.PI.4.6a, 11a, 10a

Students begin their study of motion by exploring movements and collisions with a set of materials such as toy cars, marbles, ramps, and other objects. In this way, they can test out their existing mental models of motion. Teachers can challenge students to get their vehicle to move faster or explore what happens when it collides with various objects. Students begin to ask their own **questions [SEP-1]**, predict outcomes of different combinations of motion and collision, and then try them out. From this spirit of free exploration, students record as many observations and questions as possible in their science notebooks. They can return to these questions again and reframe them in terms of energy after they have a better understanding of the energy of motion.

Teachers can focus students back on a toy car sitting on a table. Why isn't it moving? What will it take to get it to move? Students have investigated forces in kindergarten and grade three, and know that they need to push or pull the car to get it to move. A person gives energy to the car when he or she applies a force to it. Scientists like to use the phrase "transfer energy" rather than "give" because it emphasizes **flow of energy [CCC-5]** in the **system [CCC-4]**, where energy gained by one object always comes at the loss of energy from somewhere else. People do not usually feel the effects of losing energy when they push a small toy car, but pushing a real car would be exhausting. Clearly people must transfer more energy to a full-size car to get it to move than pushing a toy car. But what is energy?

Energy is a term commonly used in everyday language, but the concept of energy in science has a specific meaning and teachers need to draw attention to these differences. In science textbooks, energy is often formally defined as "the ability to do work," but an informal way to think about energy is "the ability to injure you." Table 4.3 presents a list of many different ways that a child could get injured. While a different verb describes each process, they all have the same result. In the same way, scientists have different words to describe the different forms by which energy can manifest itself. Each example of an injury in table 4.3 correlates with a different form of energy that a person absorbs, which **causes [CCC-2]** damage to the person's body. Each of these energy forms can be transformed into another by different processes—an electric stove transforms electricity into heat, an electric fan transforms electricity into motion, and a windmill does the reverse by transforming motion into electricity. Students explore many of these energy conversion processes in IS2 while IS1 focuses on the energy from motion and energy transfer.

Table 4.3. Analogies Between Injuries and Different Forms of Energy

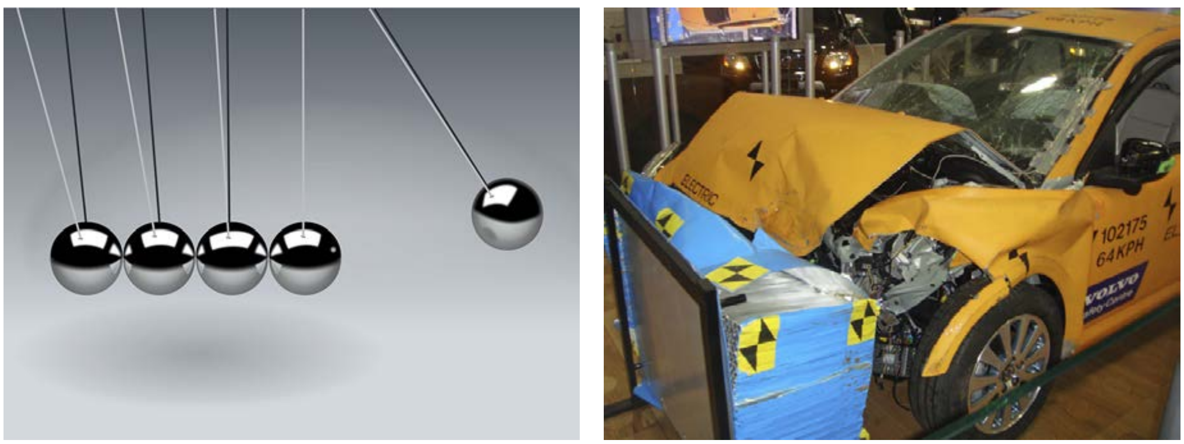
VERB PHRASE DESCRIBING AN INJURY	RELATED FORM OF ENERGY
Fell down	Gravity (gravitational potential energy)
Crashed into a wall on a bicycle	Energy of motion (kinetic energy)
Hit by a baseball	Energy of motion (kinetic energy)
Burned by touching a hot stove	Heat (thermal energy)
Electrocuted by touching an electrical outlet	Electricity (electrical energy)
Sunburnt	Light energy
Ruptured eardrums at a loud concert	Sound energy
Poisoned by accidentally drinking household cleaning products	Chemical energy (chemical potential energy)

In grade four, it is appropriate to use everyday language to describe common forms of energy (e.g., heat, electricity). In the middle grades and high school, students will label these concepts with more technical terms (shown in parentheses in the right-hand column).

Students next **plan and carry out energy investigations [SEP-3]** to explain the relationship between an object's speed and its energy. Students have an intuitive understanding of speed and can probably devise ways to measure it (e.g., the time it takes to travel a fixed distance), but energy is an abstract quantity. They need to compare the amount of energy, but in grade four the relative amounts are qualitative and not quantitative. In order to talk about amounts of energy, students also need to develop the idea that energy has **effects [CCC-2]**. Something with more energy has larger effects (e.g., does more damage when it hits a barrier or digs a bigger hole when it lands in a sand box). Which has more ability to cause damage, a moving car or a parked car? How about a car moving at five mph in a parking lot versus one traveling at 65 mph on the freeway? Students can explore the effect a rolling marble or toy car has when it hits a paper cup or another car. They can devise ways to increase or decrease the speed of their vehicle (e.g., roll it down ramps at different speeds) and then describe the effect on the paper cup (e.g., the distance the cup moved). Their measurements are evidence that they can use to **explain [SEP 6]** the relationship between an object's speed and its energy (4-PS3-1).

Students are now ready to ask more detailed questions about the effects of collisions in terms of energy and energy transfer. They can investigate what happens when different size cars collide (or tape together a stack of multiple identical cars to see the effect of a car with twice the mass) or the effects of adding a bumper of paper, clay, wood, or metal. They can compare these collisions with the collisions in a Newton's cradle where almost all the energy from one silver ball gets transferred to the other balls and a real car crash where some of the energy goes into deforming and squishing the car frame (figure 4.8). Their **investigations [SEP-3]** should be driven by student-generated **questions [SEP-1]**. Teachers can help students refine their questions in terms of energy transfer, for example: What determines the amount of energy in a collision? What determines the amount of energy that gets transferred during a collision? What happens to the energy in different types of collisions if it isn't transferred to the energy of motion? Where does the energy of motion go when a car crashes into a brick wall and stops? As they ask and refine each question, they can make and test specific predictions (4-PS3-3).

Figure 4.8. Energy Transfer During Collisions in a Newton's Cradle Versus a Car Crash



Source: Jarmoluk 2014; Duran Ortiz 2011
Long description of Figure 4.8.

IS2

Grade Four Instructional Segment 2: Renewable Energy

It takes energy to turn on the lights or move a car, but where does that energy come from? Our modern energy infrastructure involves complex chains of energy transfer between many objects and across vast distances. During IS2, students investigate several forms of energy and create devices that convert one form to another. They relate these abstract ideas about energy forms to the specific energy resources they rely on in everyday life.

GRADE FOUR INSTRUCTIONAL SEGMENT 2: RENEWABLE ENERGY

Guiding Questions

- How do we get electricity and fuel to run cars and power electronic devices?
- How does human use of natural resources affect the environment?

Performance Expectations

Students who demonstrate understanding can do the following:

4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.* [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

GRADE FOUR INSTRUCTIONAL SEGMENT 2: RENEWABLE ENERGY		
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:		
Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
[SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-8] Obtaining, Evaluating, and Communicating Information	PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.D: Energy in Chemical Processes and Everyday Life ESS3.A: Natural Resources ETS1.A: Defining Engineering Problems	[CCC-4] Systems and System Models

Highlighted California Environmental Principles and Concepts:

Principle I The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

CA CCSS for ELA/Literacy Connections: RI.4.3, 5; W.4.1, 7

CA ELD Standards Connections: ELD.PI.4.2, 10a, 11

While everyday conversations might discuss a person "running out of energy" or energy "being consumed," science refers to energy being transferred to other objects or being transformed into a different form. If an object has energy of motion (or any other form of energy), students should always ask, "Where did that energy come from?" If it appears to be losing energy (e.g., slowing down, cooling down, or getting dimmer), they should ask, "Where did the energy go?" Teachers open this segment by posing these questions about different everyday objects such as a toaster that heats up when plugged into an electrical outlet, a tablet computer whose bright screen shines using a battery, and a car that moves using gasoline.

Before understanding complex devices such as these, students conduct a series of **investigations [SEP-3]** where they observe, **model [SEP-2]**, and discuss situations where energy is transferred from one object to another, transferred from place to place, or transformed from one form of energy to another. The goal of these activities is for students to develop and refine their language for describing energy, their concept of what scientists mean when they use the term energy, and to begin to collect evidence that energy can be transferred from place to place by sound, light, heat, and electric currents (4-PS3-2). Teams of students can visit stations where each team examines different **systems [CCC-4]**, such as the following:

- Energy of motion to sound: one block collides into another block or a moving ball collides into another ball
- Elastic energy to motion: a rubber-band catapult or a trampoline
- Light energy to heat: sunlight or a heat lamp on a surface
- Chemical energy to heat and/or light: a hand warmer, a candle flame, a light stick
- Light energy to electrical energy to sound: solar panel connected to a circuit that rings an electrically-operated doorbell
- Wind energy to motion: blowing on a pin wheel or leaves moving on a tree
- Motion into heat energy via friction: rubbing hands together or sliding objects across surfaces such as sand paper and carpet
- Mechanical energy to motion: wind-up devices such as wind-up toy chicks, chattering teeth, cars, or hand crank generators spinning a fan motor
- Motion to sound: vibrating tuning forks

After exploring a few of the stations freely, the class convenes to try to come up with a list of all the different forms of energy they have observed. While they investigated the energy of motion in IS1, this is the first time they explicitly consider all the different forms of energy. They then return to the stations with their science notebooks and for each station they fill in a table with (1) the forms of energy observed, (2) changes they observed in the interactions, (3) the transfers of energy from one object to another or from one place to another, and (4) the transformations of energy (e.g., light to electrical energy). This table comprises a **conceptual model [SEP-2]** of interactions between objects. Like all models of a **system [CCC-4]**, this table describes the components of the system, how they relate or interact with one another, and can be used to **explain [SEP-6]** the behavior of the system. Their explanations should emphasize how different processes can move energy from one place to another. After experiences with systems in the real world, students can investigate computer simulations of simple systems that depict interactions that are usually invisible in the real world (PhET n.d.a).

To tie these small systems back to the broader world, students **obtain, evaluate, and communicate information [SEP-8]** about fuels and other energy sources. The energy we use to power devices like cars, computers, and homes does not disappear but instead is converted into other forms such as motion, light, or heat. This energy must come from somewhere, and students trace these chains of energy transfer back to several different sources in the natural environment. In some cases, the natural resources directly consumed to make the energy are abundant and constantly replenished so they are called *renewable* energy resources (like energy from the Sun, wind, and water). Some renewable energy sources, such as trees cut for firewood, can take several decades to grow before they can be used for fuel. Because they are not formed or accumulated over a human lifetime, some energy resources are called *nonrenewable* (like coal, oil, natural gas, and the uranium used in nuclear power plants). Obtaining energy from all these resources changes and damages the natural environment, but extracting some energy sources is much more harmful than others (California's Environmental Principles and Concepts [EP&Cs I, II, IV]). Teachers assign students to **obtain information [SEP-8]** about a specific renewable resource (e.g., wind, solar, water stored behind dams used to drive hydroelectric generation, biofuels) and nonrenewable resource (e.g., fossil fuels such as gasoline, natural gas, or coal). Students review information they find in print and digital media to discover which objects and forms of energy play a role in each energy resource; how the energy resource is used (running cars, generating heat, producing electricity); and how the use of the energy source affects the environment (EP&C II).

Engineering Connection: Renewable Energy with Low Environmental Impact

Student teams complete a design project that demonstrates some form of renewable energy with low environmental impact. Teachers can either dictate a class-wide energy challenge or allow teams to pursue their own energy projects. The emphasis is on **designing a solution [SEP-6]** that meets certain criteria, including potential environmental impacts (EP&Cs II, V) and converts energy from one form to another (4-PS3-4). Students should then test and improve their design, striving to make it a more efficient energy conversion device.

Student teams communicate their findings about different energy sources and demonstrate their energy conversion devices at a class Energy Day. They have interactive demonstrations and exhibits where students teach their families about the various forms of energy, science, technology, efficiency, conservation, environmental impacts, and careers in the energy industry.

Opportunities for ELA/ELD Connections

As part of the project about fuels and other sources that provide energy, and using the information gathered, students write an opinion piece about supporting (or not supporting) the use of renewable or nonrenewable energy resources. Their opinion pieces should consider the environmental impacts of using either renewable or nonrenewable resources (EP&C II).

CA CCSS for ELA/Literacy Standards: RI.4.3, 5; W.4.1, 7

CA ELD Standards: ELD.PI.4.10a, 11

Sample Integration of Science and ELD Standards in the Classroom

Students have been engaged in investigating the phenomena of energy transformation (4-ESS3-1). Students worked in small groups to conduct a short research project on different aspects of humans' impact on Earth's resources. They **obtained and combined information [SEP-8]** to explain how energy and fuels are derived from natural resources and how their uses affect the environment. The students used books, Internet sources, and other reliable media to work together in small groups to construct a coherent explanation of how human uses of energy derived from natural resources affect the environment in multiple ways, how some resources are renewable and others are not, and possible actions that humans could take in the future. Each small group co-developed a written explanation and prepared a digital presentation with relevant graphics to present their research.

CA ELD Standards: ELD.PI.4.2

Source: Lagunoff et al. 2015, 246–247

EP&C Connection: Students work in small groups to conduct a short research project on different aspects of humans' impact on Earth's resources and natural systems (EP&C II).

IS3

Grade Four Instructional Segment 3: Sculpting Landscapes

California's landscape has shaped our history, allowing this unit to be effectively integrated with grade four history–social science standards. Gold was first discovered in California in material eroded away from high in the Sierra Nevada and then deposited in the fertile Central Valley. In grade two, students observed how wind and water change landscapes, noting that some of the changes are slow while others are rapid. In grade four, they focus on the cause and effect relationship and look at exactly what happens when rocks get broken apart, transported, and deposited.

GRADE FOUR INSTRUCTIONAL SEGMENT 3: SCULPTING LANDSCAPES

Guiding Questions

- How do water, ice, wind, and vegetation sculpt landscapes?
- What factors affect how quickly landscapes change?
- How are landscape changes recorded by layers of rocks and fossils?
- How can people minimize the effects of changing landscape on property while still protecting the environment?

Performance Expectations

Students who demonstrate understanding can do the following:

4-ESS3-1. Identify evidence from patterns in rock formations and fossils in rock formations and fossils in rock layers for changes in a landscape over time to support an explanation for changes in a landscape over time. [Clarification Statement: Examples of evidence from patterns could include rock layers with shell fossils above rock layers with plant fossils and no shells, indicating a change from land to water over time; and, a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock.] [*Assessment Boundary: Assessment does not include specific knowledge of the mechanism of rock formation or memorization of specific rock formations and layers. Assessment is limited to relative time.*]

4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. [Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [*Assessment Boundary: Assessment is limited to a single form of weathering or erosion.*]

4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth's features. [Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.] (Introduced. Fully assessed in IS4)

GRADE FOUR INSTRUCTIONAL SEGMENT 3: SCULPTING LANDSCAPES

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.* [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [*Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.*] (Introduced. Fully assessed in IS4)

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3–5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	ESS1.C: The History of Planet Earth ESS2.A: Earth Materials and Systems ESS2.E: Biogeology ESS3.B: Natural Hazards ETS1.A: Defining Engineering Problems	[CCC-1] Patterns [CCC-3] Scale, Proportion, and Quantity

Highlighted California Environmental Principles and Concepts:

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle V Decisions affecting resources and natural systems are complex and involve many factors.

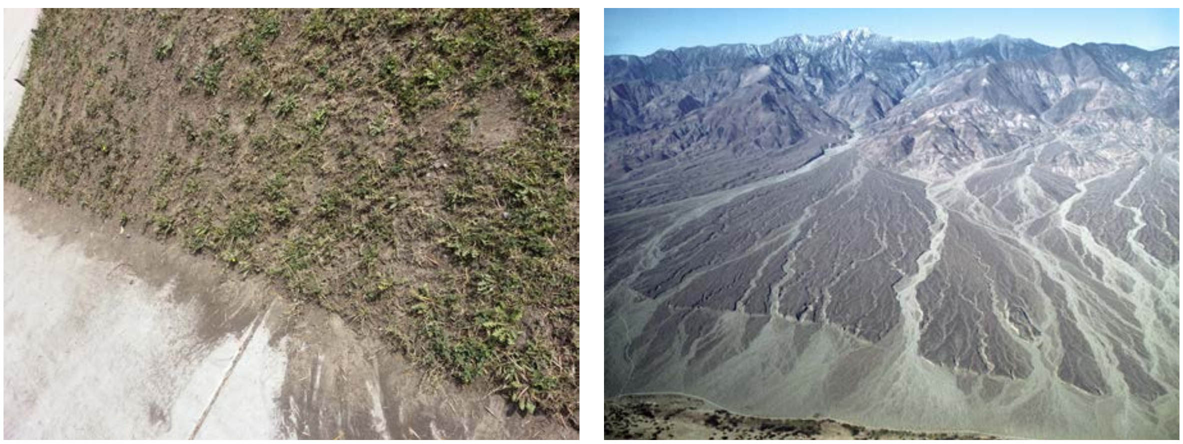
CA CCSS for ELA/Literacy Connections: W.4.3, 4, 7, 8, 10; L.4.1, 2, 5, 6

CA ELD Standards Connections: ELD.PI.4.6, 10.b

Landscapes are constantly changing as forces on Earth's surface sculpt and reshape the rocks. Sometimes these forces act quickly (sudden landslides) while other times they cause more gradual changes. Students will eventually return to the issue of timescales of these processes at a more nuanced level in high school (HS-ESS2-1), but fourth-graders begin by simply observing that there are factors that affect the speed at which landscapes change and that there are systematic patterns that cause these differences in rate.

While erosion of a centimeter of rock might take all year in real life, students can often observe the effects of water, ice, wind, or vegetation on soil in their schoolyard (figure 4.9). These processes have two types of effects on rock and soil: they (1) break material into smaller pieces and (2) transport those pieces (erosion), eventually depositing them in new places. The roots of plants squeeze their way through the soil and slowly wedge pieces apart but do not usually move those pieces very far (weathering only). Other processes often involve both weathering and erosion by the same force. Wind only has enough force to break off and blow away tiny sand and dust particles. By contrast, the force of a moving glacier made of ice was enough to slice off the missing half of Half Dome in Yosemite, literally moving a mountain (or at least half of it). In most parts of California, flowing water is the most important process that breaks apart rocks and moves them. Students should directly investigate at least one of these processes in detail.

Figure 4.9. Erosion and Deposition on the Schoolyard and in Nature



Sources: Mauney 2013; Miller 2008
Long description of Figure 4.9.

One of the most engaging and dramatic investigations of weathering and erosion by water is a **physical model [SEP-2]** of a river called a stream table (a container or tray filled with sand, clay, and/or gravel propped up on one end to represent a sloping mountainside). Because students can try out different scenarios and quickly see the results, stream tables are excellent platforms for students to **plan and carry out investigations [SEP-3]** to examine the effect of water on the rate of erosion. They can make measurements that show how different scenarios such as the type of Earth material, slope of the stream table, rate of water flow, and vegetation all affect the rate of erosion or the rate at which layers accumulate at the bottom (4-ESS2-1; See the "Instructional Strategies Snapshot: Teaching the Nature of Science Explicitly" in chapter 11 for another performance task appropriate for this performance expectation). Each group of students **constructs an explanation [SEP-6]** describing how a change they made in their experimental system **caused [CCC-2]** a change in the speed of weathering, erosion, or deposition.

Students may have used a stream table in grade two to make qualitative observations. By grade four, they can use the same tool but measure the results quantitatively. In grade two, their objective was to distinguish between slow and fast processes, but now they can vary parameters like the slope steepness and notice regular **patterns [CCC-1]** in their data over a range of steepness and describe how much faster or slower (**scale, proportion, quantity [CCC 3]**).

Students can **analyze [SEP-4]** maps of their community and predict places where erosion will happen the fastest (4-ESS2-2). These maps could show topography as different colors where students recognize that the steepest slopes have the most erosion, or simplified geologic maps that indicate the strength of different rocks and therefore their resistance to erosion.

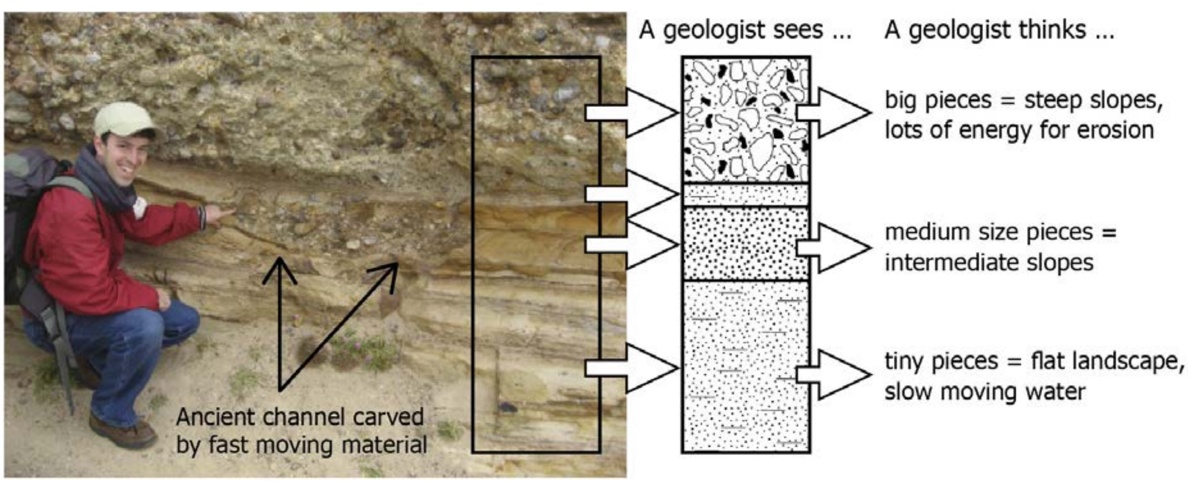
Engineering Connection: Minimize Damage to Property from Erosion

Because flowing water erodes so quickly, most natural rivers erode their banks causing the river to move and flow. Many property boundaries and even the southeastern edge of the State of California at the Colorado River are defined by the location of rivers. As the bank erodes away, people's properties can get smaller and houses can have their foundation eroded away so that they eventually fall down. In a stream table, students can generate and test multiple solutions that prevent the risk of damage to property from this natural hazard (4-ESS3-2; 3–5-ETS1-2; 3–5-ETS1-3). As they reinforce the property, how does the engineering solution affect the natural environment (EP&C III)? When people decide whether or not they will build some sort of protection, they must weigh both the benefits to their property and the damage to their neighbors' properties and to the natural river system (EP&C IV).

Stream tables also allow students to directly investigate how some types of rocks form in layers. When water slows down at the bottom of the stream table, the water no longer pushes the pieces of sand and soil with enough force to move them, so they settle down in a layer. The same thing happens in real life as material eroded from mountains drops out of rivers when the water slows down on the flatter valleys below or when it slows even more as it reaches a slow moving lake or the ocean. Students can place leaves at the bottom of the stream table and watch how they get buried (the first stage in fossil formation). As vegetation and animals in an area change over time, the types of leaves and animal remains that get buried and fossilized also change. The assessment boundary for 4-ESS1-1 states that students do not need "specific knowledge of the mechanisms of rock formation," but understanding how rock layers record changes in landscape does require at least some general understanding of how these layers accumulate. The assessment boundary is designed to signal teachers that students will investigate the processes of rock formation in the middle grades. Material that is often covered in elementary school, such as the classification of rocks into three main types and the rock cycle, are therefore not a part of grade four. Instead, the learning progressions in the California Next Generation Science Standards (CA NGSS) (appendix 1 of this framework) and the performance expectations indicate that grade four focuses on rocks that form at the Earth's surface (primarily sedimentary rocks).

Once students have a basic model for how layers accumulate, they can **interpret data [SEP-4]** from fossils and rock type to infer changes that occurred to the landscape at a particular location (4-ESS1-1). Each layer of rock reveals clues about the environment in which it formed in both the rock material itself (such as the size of the individual pieces that make it up (figure 4.10) and the fossils contained in each layer (building upon LS4.A from grade three about how fossils provide evidence of the environment in which they formed). Students can use observations from famous national parks like the Grand Canyon or more local settings for which geologic studies exist. Ideally, students can take field trips to local exposures of rock layers in their community, but they can also practice interpreting rock layers by examining the different types of concrete and building materials on their own schoolyard (USGS 2015a).

Figure 4.10. Layers of Rock Record Changes in Landscapes



Scientist near Point Reyes Lighthouse in California points out rock formation layers. *Source*: M. d'Alessio
Long description of Figure 4.10.

Opportunities for ELA/ELD Connections

As part of an investigation about rocks, rock formations, and the components in rocks that provide evidence of changes in a landscape over time, students take notes, paraphrase, and categorize information by creating an *I Am a Rock* book. Students can write the information from the point of view of a rock in their investigation, including a description of what it is made of, how it formed, how it provides evidence of changes in the landscape, etc. Students include pictures throughout, as well as a list of sources at the end of the book.

CA CCSS for ELA/Literacy Standards: W.4.3, 4, 7, 8, 10; L.4.1, 2, 5, 6

CA ELD Standards: ELD.PI.4.6, 10.b

IS4

Grade Four Instructional Segment 4: Earthquake Engineering

All regions of California face earthquake hazards. In this unit, students use the phenomenon of earthquakes to introduce the physical science concept of waves. The CA NGSS emphasize waves because electromagnetic waves play a fundamental role in modern technology (communications and medical imaging, among other applications). Grade four students do not yet study abstract electromagnetic waves, but instead **develop models [SEP-2]** of more tangible waves that cause objects to have a repeating **pattern [CCC-1]** of motion.

GRADE FOUR INSTRUCTIONAL SEGMENT 4: EARTHQUAKE ENGINEERING

Guiding Questions

- How have earthquakes shaped California's history?
- How can we describe the amount of shaking in earthquakes?
- How can we minimize the damage from earthquakes?

Performance Expectations

Students who demonstrate understanding can do the following:

4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.] [*Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.*]

4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth's features. [Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

GRADE FOUR INSTRUCTIONAL SEGMENT 4: EARTHQUAKE ENGINEERING

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.* [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [*Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.*]

3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3–5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	PS4.A: Wave Properties ESS3.B: Natural Hazards ETS1.A: Defining Engineering Problems ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution	[CCC-1] Patterns [CCC-6] Structure and Function

Highlighted California Environmental Principles and Concepts:

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

CA CCSS Math Connections: 3.MD.7b; 4.NF.7, 5.G.1

CA CCSS for ELA/Literacy Connections: SL.4.2; W.4.8

CA ELD Standards Connections: ELD.PI.4.6, 11

Many children in California have never felt an earthquake, though they know about them from family stories, media, and school disaster drills. Teachers can begin by hearing what students already know about earthquakes. They can show maps of recent earthquakes in California, read stories about important earthquakes in the history of California (including the 1857 Southern San Andreas, 1868 Hayward, 1872 Lone Pine, and the Great 1906 earthquake in San Francisco) as well as more modern earthquakes that their parents or grandparents may have felt (1971 San Fernando, 1989 Bay Area, 1994 Northridge).

Opportunities for Mathematics Connections

Where do earthquakes usually strike in California? How about the rest of the world? Students can take a list of the longitude and latitude of earthquake epicenters and plot them on a map (CA History–Social Science Standards 4.1.1; this skill is not part of the CA CCSSM until grade five, 5.G.1). Depending on the skill level of the students, the longitude and latitude should probably be rounded to the nearest whole number and students can plot them on a world map. Students who have greater mastery of decimal numbers (4.NF.7) can use locations rounded to the nearest tenth of a degree, which makes the locations detailed enough to plot on a map of California. To reveal key **patterns [CCC 1]**, students will need to work together to plot a large number of data points (100-200 earthquakes). Students should then **ask questions [SEP-1]** about the patterns they see. Students are likely to discover that earthquakes cluster in certain areas (including California) and there are large areas on the globe where very few earthquakes occur. In the middle grades, students will explain these patterns in terms of plate motions and the internal forces. In grade four, students are only responsible for describing patterns (4-ESS2-2) and asking questions about what might cause these patterns.

Teachers might be surprised to see a large number of earthquakes in Oklahoma, which has experienced more earthquakes per year than California since 2014. US Geological Survey scientists have documented that this increase is due almost entirely to wastewater from the oil and gas industry pumped deep into the ground (Weingarten et al. 2015; Ellsworth et al. 2015). This dramatic change in just a few years is a powerful example of how humans can disrupt natural cycles (EP&C III) and that altering these natural cycles affects human lives (EP&C IV).

CA CCSSM: 4.NF.7; 5.G.1

What does it feel like to be in an earthquake? Students can describe what they see in video clips of major earthquakes. How do objects move when they are attached to the ground? What happens when they are not attached? Students should be able to observe the clear back-and-forth motion during earthquake shaking. The shaking may start off gently, suddenly become severe, and slowly die back down. When students look at videos of the same earthquake from different locations, how does the shaking compare? The strength and duration of shaking a person experiences during an earthquake depend on many factors, including the amount of energy released in the earthquake, the distance the person is from the earthquake source, and the rigidity of the ground underneath the person. Grade four students are not expected to know or be told about these differences. They should focus on describing similarities and differences between different earthquake observations and **asking questions [SEP-1]** about what influences the shaking.

Students must then **develop a model [SEP-2]** of earthquake shaking. They can start with a physical model where they move their hands back and forth, reproducing the intensity of shaking by the distance they move their hands and the timing of the shaking by how quickly they must vibrate them back and forth. They can observe how this shaking forms a visible wave when they hold one end of a wire, string, or toy spring and repeat the motion. The farther up and down they move their hand, the farther up and down the string moves at its peaks (figure 4.11, left side). Students might also notice that the wave becomes longer and broader when they slow down their shaking (figure 4.11, right side). They have discovered two key aspects of describing waves: amplitude and wavelength. In earthquake waves, the amplitude is the intensity of the shaking while the wavelength relates to how quickly the movement repeats (figure 4.12). Teachers can have students practice using pictorial models of seismic waves by asking them to measure the wavelength and amplitude at different points in the recordings of famous California earthquakes, determine where the shaking would be most severe on each recording, and compare the shaking amplitude from different earthquakes.

Figure 4.11. Physical Model of Waves with a String

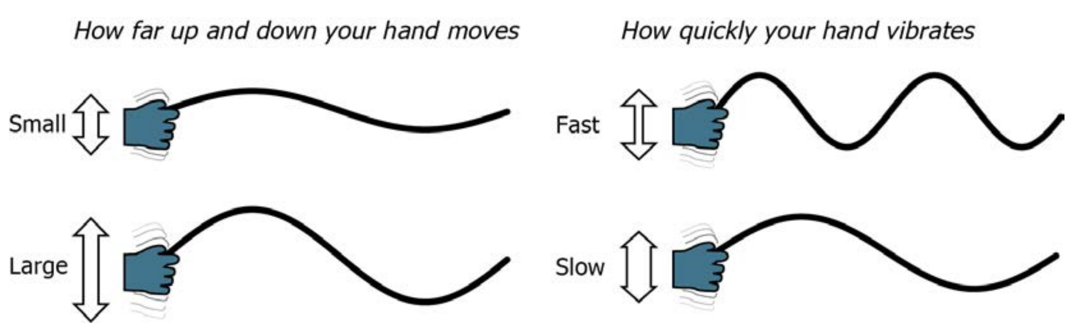


Diagram by M. d'Alessio
Long description of Figure 4.11.

Figure 4.12. Pictorial Model of Simple Waves and Earthquake Shaking

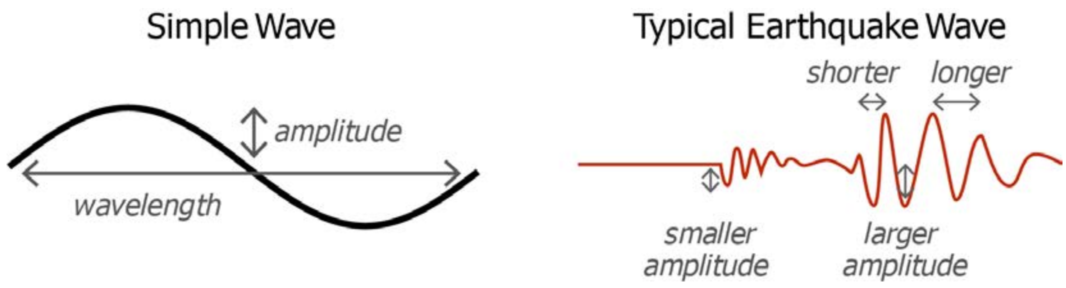


Diagram by M. d'Alessio
Long description of Figure 4.12.

It is not scientifically accurate to describe the width of an earthquake wave from a seismic recording graph as *wavelength* because the horizontal axis on these graphs is time, not length. This distinction is not important for grade four students and students can see how different parts of the earthquake wave have different lengths on the graph just like they can describe different wavelengths in real life.

Lastly, students can view computer visualizations of earthquake waves traveling across the surface (USGS 2016). Students see that earthquake waves appear like ripples on a pond or waves moving across the open ocean. They are in fact all examples of waves whose motion can be described using wavelength and amplitude.

Opportunities for ELA/ELD Connections

Students view two to three different videos on waves and use a note-taking template, such as a T-chart, to capture key information. On the left-hand side of the T, provide students with broad concepts for waves—light waves, sound waves, characteristics of waves, behaviors of waves (reflected, absorbed, transmitted), and examples of movement of energy. On the right-hand side, prompt students to include details gleaned from the videos. Possible sources of videos include Vimeo, YouTube, or recognized science experts (e.g., Bill Nye).

CA CCSS for ELA/Literacy Standards: SL.4.2; W.4.8

CA ELD Standards: ELD.PI.4.6, 11

Engineering Connection: Design a Home to Withstand an Earthquake

While earthquakes are a part of life in California, people can protect themselves from harm. California communities have adopted and enforce strict building codes so that every new building constructed must be designed using earthquake-safe techniques and be inspected by trained engineers prior to being used. These building codes are the difference between life and death. Fewer than 75 people died in each of the last three large earthquakes near cities in California (1971, 1989, 1994). More people die of preventable heart disease in California every day than died from these three earthquakes that took place over a span of more than two decades (CDC 2015). By contrast, a comparable earthquake in Bam, Iran in 2003 killed more than 25,000 people even though it was smaller than any of the California earthquakes. The difference is that homes in Iran were not constructed to the same standards as California buildings. Students will design a structure that can withstand earthquakes so that its occupants stay safe during the next "Big One." (4-ESS3-2).

Teachers should introduce a scenario in which students design a home that is big enough to hold a family and is capable of withstanding a strong earthquake. Teachers can construct a simple shake table where students will test out their designs (Teach Engineering 2010). First, students must **define the problem [SEP-1]** by deciding on criteria for success (3–5-ETS1-1). How long must the structure endure shaking before it can be certified as safe? What will the amplitude of the ground shaking be during the test? What counts as falling down? For example, if the structure tilts to the side during the test, is it still certified as safe? They then must work with the constraints given to them by the teacher. They use only the provided materials (interlocking plastic bricks, toothpicks and gumdrops, spaghetti strands and masking tape, index cards and transparent tape, etc.). Students calculate the area of their home's usable floor space to make sure it meets the minimum size requirements (CA CCSSM 3.MD.7b).

Each group of students generates a possible design that may **solve the problem [SEP-6]** and tests it out on the shake table (3–5-ETS1-3). Students quickly realize that they must be as consistent as possible with the shaking in order for the tests to be fair. Students then compare the different designs to determine which strategies worked best (3–5-ETS1-2). They modify their designs for a second trial and see if their improved structure can withstand stronger shaking. They create a presentation of their design to a future homeowner with diagrams that illustrate the **structural features [CCC-6]** they use to ensure the family's safety.

IS5

Grade Four Instructional Segment 5: Animal Senses

The CA NGSS in grade four present a number of related performance expectations around how animals sense and process information. Students can develop a model that unifies external sensing organs, the internal brain structures that support them, the principles of information processing, and how all these processes work together to help organisms survive and thrive in the world. Because these ideas integrate so many concepts, this instructional segment represents a strong capstone to grade four.

GRADE FOUR INSTRUCTIONAL SEGMENT 5: ANIMAL SENSES

Guiding Questions

- How do the internal and external structures of animals help them sense and interpret their environment?
- How do senses help animals survive, grow, and reproduce?
- What role does light play in how we see?
- How do humans encode information and transmit it across the world?

Performance Expectations

Students who demonstrate understanding can do the following:

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. [Clarification Statement: **Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin. Each structure has specific functions within its associated system (CA).**] [*Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.*]

4-LS1-2. Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways. [Clarification Statement: Emphasis is on systems of information transfer.] [*Assessment Boundary: Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.*]

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen. [*Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.*]

4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.* [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1s and 0s representing black and white to send information about a picture, and using Morse code to send text.]

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

California clarification statements that are bolded and followed by **CA** *were incorporated by the California Science Expert Review Panel.*

GRADE FOUR INSTRUCTIONAL SEGMENT 5: ANIMAL SENSES		
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:		
Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS1.A: Structure and Function LS1.D: Information Processing PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and System Models [CCC-5] Energy and Matter: Flows, Cycles, and Conservation [CCC-6] Structure and Function [CCC-7] Stability and Change
Highlighted California Environmental Principles and Concepts: **Principle I** The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services. **Principle II** The long-term functioning and health of terrestrial, freshwater, coastal, and marine ecosystems are influenced by their relationships with human societies.		
CA CCSS Math Connections: 4.OA.5; 4.MD.5, 6; 4.G.3; MP. 2, 4, 5, 6		
CA CCSS for ELA/Literacy Connections: W.4.1; RI.4.3, 7		
CA ELD Standards Connections: ELD.PI.4.10		

This instructional segment is very broad and interconnects life sciences and physical sciences. This description of the instructional segment starts with a focus on the content connected to the internal and external structures of plants and animals and how these structures support their survival, growth, behavior, and reproduction. The remainder of the instructional segment description focuses on how various sensory receptors, a specific group of internal structures, are used to help organisms collect information, which they then process and use for survival and reproduction.

Students begin with observations to **construct explanations [SEP-6]** and **develop models [SEP-2]** for how plant and animal structures function to support survival, growth, behavior, and reproduction. They can begin their study by taking a walking field trip to a school or local garden, community park, or nature preserve. Each student chooses a plant or animal to carefully observe and sketch. The goal of drawing the organism is to identify different **structures [CCC-6]** and **ask questions [SEP-1]** about how they help the organism survive. These questions set the stage for gathering evidence. Based on further observations, research, and classroom and outdoor experiences, students **construct an argument [SEP-7]** about the importance of specific structures of an insect to its survival, growth, behavior, and reproduction. Together, student teams can use a “Questions, Claims, and Evidence” format to organize their argument that structures of their organism function to support survival, growth, behavior, and reproduction.

GRADE FOUR VIGNETTE 4.2: STRUCTURES FOR SURVIVAL IN A HEALTHY ECOSYSTEM

Performance Expectations

Students who demonstrate understanding can do the following:

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. [Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin. Each structure has specific functions within its associated system.] [*Assessment Boundary: Assessment is limited to macroscopic structures within from one of California’s systems.*]

4-LS1-2. Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways. [Clarification Statement: Emphasis is on systems of information transfer.] [*Assessment Boundary: Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.*]

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-2] Developing and Using Models [SEP-7] Engaging in Argument from Evidence	LS1.A: Structure and Function LS1.D: Information Processing	[CCC-4] Systems and System Models [CCC-6] Structure and Function [CCC-7] Stability and Change

Highlighted California Environmental Principles and Concepts:

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

CA CCSS for ELA/Literacy Connections: W.4.1, SL.4.1, SL.4.4, SL.4.5

CA ELD Standards Connections: ELD.PI.1-3, 5, 9-11

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Introduction

Mr. F thinks it is very important for students to explore natural **systems [CCC-4]** outside of their classroom rather than just reading about them in books. He plans ahead for a field trip outside of the classroom so students become active observers of the natural world and learn about the internal and external structures of plants and animals where they live. Mr. F's experience tells him that observing living organisms in nature would be the best strategy for teaching students about the functions of external structures in growth, survival, behavior, and reproduction.

Preparation for a Field Investigation

Students work with the art teacher to develop their skills for making plant and animal drawings in their science notebooks.

Day 1: Getting Ready for a Field Trip

Students brainstorm about the plants and animals they might observe during their field trip and discuss the types of external structures they might see.

Day 2: Observing External Structures in Nature

Students undertake a field investigation in the neighborhood and record the plants and animals they see in their science notebooks.

Day 3: Structures for Survival

Students identify external structures and add drawings to their science notebooks for the plants and animals they observe. They make claims about how they aid in survival.

Day 4: External Structures in California Habitats

Students investigate California's diverse habitats and investigate differences in the external structures of plants and animals that live there.

Day 5: Survival in Changing Habitats

Students develop pictorial models representing all of the information they have gathered about plants' and animals' external structures. They then use the models to test an interaction relating to the functioning of a natural system.

Preparation for a Field Investigation

Anchor phenomenon: Different animals and plants have different external parts.

The week before the field trip, Mr. F asked the art teacher to prepare the students by helping them learn how to draw various local plants and animals. He mentioned to her that the students would be focusing on the external structures of these organisms so it would be especially helpful if they learned how to draw items like beaks, wings, feet, tails, leaves, flowers, branches, roots, seeds, and nuts. At that time, Mr. F also enlisted three of his parent volunteers to work with the students during the field trip.

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Day 1: Getting Ready for a Field Trip

The day before their field trip, Mr. F asked students what plants and animals they think they might see near the school and in the park. Since many of the students were very interested in nature, the class came up with a list of 10 different animals they had previously seen on campus; five birds and 10 plants they observed in the park; and several of the plants and animals that they were familiar with from visits to a local nature center. He divided the students into groups of four and asked them to choose one plant and one animal from the class list that they wanted to discuss as a group. Mr. F instructed them to write in their science notebooks the name of their chosen plant on one page and their animal on another page. Students then made a list of at least three external structures for each of their organisms. Mr. F's students were familiar with the idea of external structures from grade one (1-LS1-1), but most used the term *external parts*. Mr. F introduced the term *structure* and related the word to other uses in English. One member of each group went to the board and wrote the names of their group's plant and animal, and the external structures they identified. When all of the groups had shared their organisms and external structures on the board, Mr. F sent students on a "gallery walk" around the room during which they added suggestions to other teams' lists using a different color pen. When the lists had been completed, Mr. F asked the class, "What **patterns [CCC-1]** do you see in the types of external structures among the different animals?" and "What patterns do you see among the different plants?" Students recorded additional ideas about the external structures in their science notebooks. This process provided the students with lists of external structures they could look for during their outside exploration.

Mr. F reminded students that they were going on an off-campus field trip the next day and that they should bring along shoes that could get dirty or muddy.

Day 2: Observing External Structures in Nature

Investigative phenomenon: Different animals and plants live in different sections of their neighborhood.

On the day of their field trip, Mr. F briefly reminded the students how they need to behave while they are walking around the neighborhood: stay with the adults working with their groups; move and speak quietly so that they do not disturb the animals they are trying to observe; avoid littering; etc. He then explained the information they were going to collect during the **investigation [SEP 3]**, including observations of the plants and animals that live nearby—paying close attention to their external structures, such as beaks, wings, leaves, etc. Mr. F reminded students that as they were making their observations, they should pay special attention to the external structures of the organisms, making notes in their science notebooks.

Mr. F told students to put on their outside shoes and take along their pencils and science notebooks. An art teacher and/or a teacher or community volunteer with artistic expertise joined the class when they were ready to head out for their neighborhood exploration.

Students started with a 20-minute investigation of the schoolyard and a small park in the neighborhood. They observed some birds flying by, and he asked them to identify some of the

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external features of the birds, wings, beaks, and eyes. The students saw a squirrel running across the grass, so Mr. F asked them to identify some of the interesting features of the squirrel: long tail, big eyes, claws, and large ears. They had noticed the squirrel climbing up a big oak tree, so he asked them to identify some of the tree's external features: trunk, bark, branches, leaves, roots, and acorns.

When they return to the classroom, the class quickly compiled a list of the names of the plants and animals they observed during their field trip.

Day 3: Structures for Survival

Investigative phenomenon: Students only observed a few animals on their nature walk.

Mr. F had students return to their small groups and called their attention to the list of plants and animals they observed the previous day. Students were surprised at how they only observed a few of the animals they listed in their science notebooks on day 1. Some students suggested it might have been too hot during the field trip for the animals to be out. Others proposed that their original lists were different because they were visiting the area during a different season. Yet others said that the differences were a result of the drought in their area over the past year (**stability and change [CCC-7]**). A few mentioned that they thought that recent construction activities in the area disturbed the plants and animals (EP&C II).

Investigative phenomenon: Different plants and animals have different external structures and also different behaviors.

Mr. F asked groups to select a plant and an animal that they observed during the field trip, explaining that they must choose organisms different from those they had previously written about in their science notebooks. Following what they did on day 1, students wrote the name of their chosen plant on one page of their science notebook and their animal on another page. Below the organisms' names, students drew simple **pictorial models [SEP-2]** of each organism, including the external structures with labels. Mr. F mentioned that as they made these drawings they should think about how each of the structures may be helping the plant or animal survive.

Mr. F put a sample chart on the board which students copied in their science notebooks, making as many rows as there were student groups. To initiate the class discussion, he asked one group to name its organism and identify some of the external structures the group observed.

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Name of Plant or Animal	External Structures Observed	blank	blank
Gray squirrel	Claws	blank	blank
(add more rows as needed)		blank	blank

Mr. F deepened the discussion by having students explore the importance of these **structures and functions [CCC-6]** by giving them two written prompts: Describe how the plants and animals use the external structures you observed. and Explain how the structures aid the plants and animals in survival. They added labels to the blank columns of their charts for each of these prompts.

Name of Plant or Animal	External Structures Observed	Use of the External Structures	How the Structures Aid in Survival
Gray squirrel	Claws	Climbing trees and gathering acorns	Escaping predators and supplying the food they need to survive

After all groups responded in their science notebooks, Mr. F had each group approach the board and enter its information in the chart. As one group entered its information, the group described and explained its claims about the survival value of the external structures they identified. Mr. F asked, "What do others think about this claim? Is there anything that you would like to add or change?" As others contributed, some of the groups made additional notes in the chart, modifying their claims or adding other evidence. All students recorded information from the final chart in their science notebooks.

Day 4: External Structures in Changing California Habitats

Investigative phenomenon: Different plants and animals grow in different parts of California.

In an effort to help students discover the natural diversity of habitats, plants, and animals in California, Mr. F called their attention to a habitats wall map (https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link8). He also saw this as an opportunity for integration between standards in science and History–Social Science (3.1.1) where they learned about geographical features in their local region including deserts, mountains, valleys, hills, coastal areas, oceans, and lakes. After looking closely at the map, students shared their observations mentioning that there are many different habitats in California: several students said that they have never visited the desert or the mountains; others mentioned that they have never seen the coast or ocean. Mr. F prompted the students to discuss the plants and animals that live in each of California's

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habitats (the poster has pictures of the plants and animals grouped with each habitat). Several of the students expressed great interest in learning about the different habitats, so Mr. F mentioned that he had included the book *California's Natural Regions* (https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link9) in the class backpack of "habitat tools"—students get one week to take the backpack home and engage in the activities in the backpack with their family.

Mr. F pointed out their local region and, using the map and their local knowledge, asked students to write the names of some plants and animals that live near their community. He then prompted them by asking, "Do you think that the plants and animals that live in other habitats will have different external structures than the organisms that live near them?" Several students raised their hands rapidly to point out that the external structures of the organisms that live in coastal and marine ecosystems will be very different; many will have fins, gills, large tails for swimming, and tentacles for gathering food and moving. Mr. F encouraged students to identify different external structures they might see in freshwater and streams.

Investigative phenomenon: The Merriam's kangaroo rat has specific external structures.

Mr. F distributed copies of a photograph of a common animal in California's deserts, the Merriam's kangaroo rat (see Structures for Survival in a Healthy Ecosystem at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link10). He asked them to use the blank spaces to label the animal's major external structures including its eyes, nose, feet, tail, and cheeks. Turning over the paper, students responded to each of the writing prompts by explaining how the structures help kangaroo rats grow, reproduce, and survive. Several of the students were surprised that there was an arrow pointing to the animal's cheek and asked Mr. F why. He told them that kangaroo rats use cheek pouches to store seeds collected from the desert floor until the rats can bury the seeds near their burrows. He asked students to share their arguments about the function of one of the kangaroo rat's external structures. The class worked together to decide the top three arguments for the function and role in survival of each of the kangaroo rat's external structures.

Day 5: Survival in Changing Habitats

Investigative phenomenon: Different plants and animals have different external structures and also different behaviors. (Students return to this phenomenon from day 3.)

As a formative evaluation activity, Mr. F asked students to **analyze and interpret [SEP-4]** their data from day 4 as the basis for developing **pictorial models [SEP-2]** which would help them identify interconnections and **cause and effect [CCC-2]** relationships between the external structures of animals and plants, and their survival. Their initial models (figure 4.13) identified the plant or animal, their major external features, and the role of each structure in survival.

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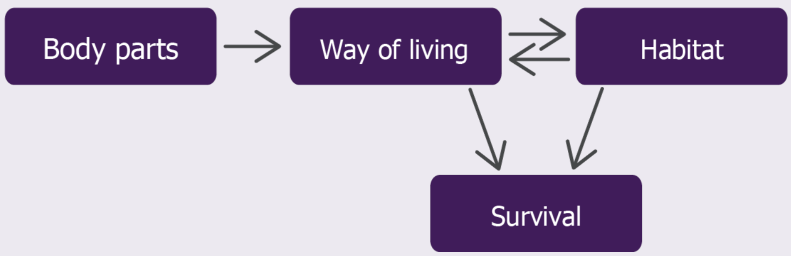
Mr. F explained that they would be making **arguments supported by observational evidence [SEP-7]** regarding the role of external structures in the survival of organisms in different habitats. He reminded students that their arguments must include evidence they gathered in support of their point of view and include their reasoning to support the structure's role in survival, growth, behavior, and/or reproduction. They posted their models around the class and used the evidence summarized in their models to make an evidence-based argument for the importance of the external structures they investigated to their organism's survival. Mr. F asked other students if they could add any more information or suggestions that would allow each presenter to strengthen their evidence or argument. Students then had the opportunity to adjust their models to clarify the interactions among the components of the model.

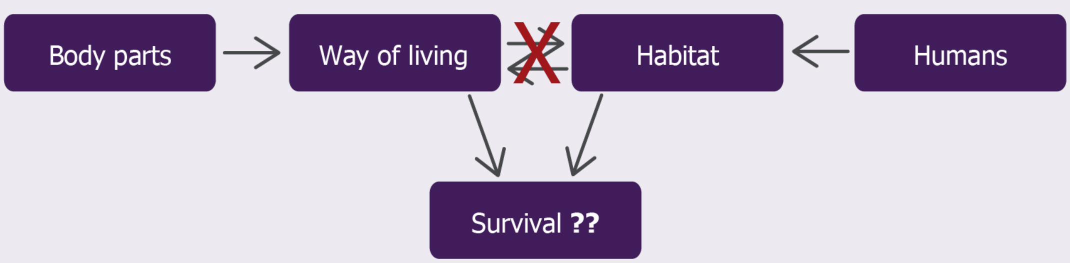
Figure 4.13. Initial Survival Model



Students use the phrases "body parts" and "way of living" to describe **structure and function [CCC-6]** relationships (LS1.A). The two arrows in grey indicate that organisms function well in a specific habitat (LS4.C). Resources in the habitat and the organism's abilities and behaviors allow it to survive. Diagram by G. Lieberman and M. d'Alessio.
Long description of Figure 4.13.

Mr. F asked the students to recall their many conversations about how human activities can influence the environment (EP&C II). Which components and interactions in the model can humans affect? Students agreed that people have the most influence on habitats (figure 4.14).

Figure 4.14. Survival Model Highlighting Human Influence



Students identify how humans **affect [CCC-2]** habitats such that their existing way of living is changed. This puts survival into question (LS2.C, LS4.D). Diagram by G. Lieberman and M. d'Alessio.
Long description of Figure 4.14.

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Mr. F asked students, "How might human activities that damage a habitat affect your plant's or animal's survival, growth, behavior, and/or reproduction." They used their models to develop a claim about the effects of habitat loss on their organism's survival.

Vignette Debrief

The major theme of these lessons was the interplay between the external **structures and functions [CCC-6]** of plants and animals, their habitats, and their role in survival growth, and reproduction. Notice how the investigative phenomena were all very similar to one another as Mr. F revisited several related examples. In fact, these phenomena are very similar to snapshot 3.1 from kindergarten ("Rivers have a wide variety of plants and animals that live near them") and snapshot 4.4 from grade 3 ("Some places on the school yard have lots of plants and animals while other places have fewer"). In earlier grades, they focused on describing **patterns [CCC-1]** in diversity, and this is the first time they really included these **causes [CCC-2]** in their rudimentary models. Students will revisit this same observation over and over again in the middle grades and high school, and each time they will be able to **explain [SEP-6]** the observed diversity with a deeper understanding of the **causes and mechanisms [CCC-2]**.

SEPs. Students had an opportunity to undertake a field **investigation [SEP-3]** where they could observe local plants and animals in their natural environment. Students created **pictorial models [SEP-2]** that represented the results of their investigations by identifying the plants or animals they had chosen. Their models showed the interconnections between major external features of their organisms, the role of each structure in survival, and the relationships between the external features and the ecosystem where each organism lives.

DCIs. Students mastered the fundamental connections illustrated in figures 4.13 and 4.14, including how organisms' structures help them to survive (LS1.A), how different organisms survive in different habitats (LS4.C), and how humans influence habitats and can jeopardize survival (LS2.C, LS4.D).

CCCs. On day 2, students observed structures. On day 3, they linked these **structures to specific functions [CCC-6]** within a habitat. At the elementary level, students focused on structures that they could directly observe. They identified **patterns [CCC-1]** where certain structures recurred in specific habitats, but they didn't yet examine what caused these patterns. (An ideal student might say, "Lots of plants in deserts have sharp spines. Spines must help the plants survive in that habitat. I wonder how they all got spines.") In the middle grades, they will expand their understanding to microscopic structure/function relationships as well as look at how natural selection explains structure/function relationships in terms of **cause and effect [CCC-2]**.

EP&Cs. Students delved into the question of how environmental changes caused by humans might affect the usefulness of the external structures and their organism's survival (EP&C II).

CA CCSS Connections to English Language Arts and Mathematics. These lessons offer several opportunities for teachers to make interdisciplinary connections. In

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preparation for their field investigation, students worked with an art teacher to strengthen their skills in drawing local plants and animals, as well as their external structures so they could **communicate their findings [SEP-8]**.

On day 1, the students brainstormed about the plants and animals they might see during their field trip. They then held a class discussion about the types of external structures they might see among the plants and animals in their local community, preparing them for what they would be observing during their field trip.

On day 2, with assistance from the art teacher and parent volunteers, Mr. F gave students an opportunity to participate in a field trip so that they could observe plants and animals in their local settings. They made notes in their science notebooks, gathering evidence they would use through all the remaining lessons.

On day 3, students began to summarize their data in both drawings and charts (SL.4.5) when they identified a plant or animal and described the use of the external structures. They then considered where their organism lived and described their initial thoughts about how each external structure aided the plant or animal in survival. The groups described and explained their **claims supported by observational evidence [SEP-7]** about the survival value of the external structures and engaged in discourse with other students to gain their advice and additional ideas.

Day 4 expanded students' knowledge about the natural diversity of habitats, plants, and animals in California. Using a natural habitats map, students identified California's major ecosystems and the plants and animals that lived in each. They **investigated [SEP-3]** the organisms and compared the external structures of plants and animals in different habitats. Using writing prompts, Mr. F asked students to share their arguments about the function of a kangaroo rat's external structures.

On day 5 students develop a **pictorial model [SEP-2]** that identified interconnections and **cause and effect [CCC-2]** relationships between external structures and the survival of plants and animals. They shared their models and then tested the effects of human-caused changes to habitats on the survival of the organisms they were studying. As a formative assessment, students engaged in **argument using evidence [SEP-7]** making a case about the effects of human-caused habitat damage on the survival of the plants and animals that live there (W.4.1).

Vignette prepared by the State Education and Environmental Roundtable.

Resources:

California Education and the Environment Initiative. 2013. *California's Natural Regions*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link11.

———. 2013. *Habitats Map*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link12.

———. 2013. *Structures for Survival in a Healthy Ecosystem*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link13

Structure and Function in Vision

According to the evidence statement for 4-LS1-1, students should be able to make a claim about a single structures/function relationship, emphasizing the relationship between external structures and the internal systems related to them. This section uses the phenomenon of animal vision because it connects to other performance expectations at this grade level to create an integrated theme within the instructional segment. Students observe pictures of different animal heads and eyes (figure 4.15). How many eyes does the animal have? How big are they? Where on the head are they located? Many spiders and insects have multiple eyes, but every big animal (vertebrate) that they look at has two eyes. The eyes differ in size, color, shape, and where they are located on the animal's head, but there are always two. This commonality is related in large part to common evolutionary history, but the differences have big effects on what and how animals see.

Figure 4.15. Animal Eyes

Sources: David~O 2008; Cattoir 2011; Haen 2012; Hume 2009; Art G. 2007; Haggblom 2013
Long description of Figure 4.15.

Students need to **develop a model [SEP-2]** of how these different eye **structures allow different functions [CCC-6]**. Students can begin by using a camera as a physical model. When students point a camera in a particular direction, there are objects that appear in the frame and objects that they cannot see. Human and animal eyes have a similar *field of view*. Students measure their own personal field of view as an angle by drawing a protractor on the ground and then having friends try to sneak up from behind, recording the angle at which they are first detected (CA CCSSM 4.MD.5, 6). Students **construct an argument [SEP-7]** that animals with eyes on the side of their head will survive better because they can see predators sneaking up on them from more directions. The camera model also demonstrates another function of eyes. A camera has only one "eye," making certain optical illusions possible (figure 4.16). Students explore how their two eyes provide them depth perception through games and challenges where they operate with only one eye open (such as trying to catch a falling object or drop a penny into a bucket). Students **develop a conceptual model [SEP-2]** of depth perception that describes how both eyes need to see the same object from slightly different angles. Having two eyes near one another looking in the same direction helps accomplish this function. Students sort through the pictures of animal eyes along with information about what they eat and how they live. Students identify the animals they think might have the best depth perception. What do they have in common? Why would some animals benefit from better field of view versus better depth perception? Students **obtain information [SEP-8]** from an article that describes how animals use vision to survive and find food. This activity expands on their understanding of the predator-prey relations that they learned about in kindergarten, (including labeling these relationships with the terms predator and prey, which may not have been done in kindergarten). Students **construct an argument [SEP-7]** that animals with eyes close together will be better predators because their superior depth perception allows them to see and then capture moving objects such as prey that is trying to escape. Given information about a fictional animal's eating and living habits, students can creatively draw a picture of the animal, including **applying their model [SEP-2]** of the relationship between eye position and survival needs.

Figure 4.16. Cameras with One Lens Lack Depth Perception

Source: Lock 2008
Long description of Figure 4.16.

Opportunities for Mathematics Connections

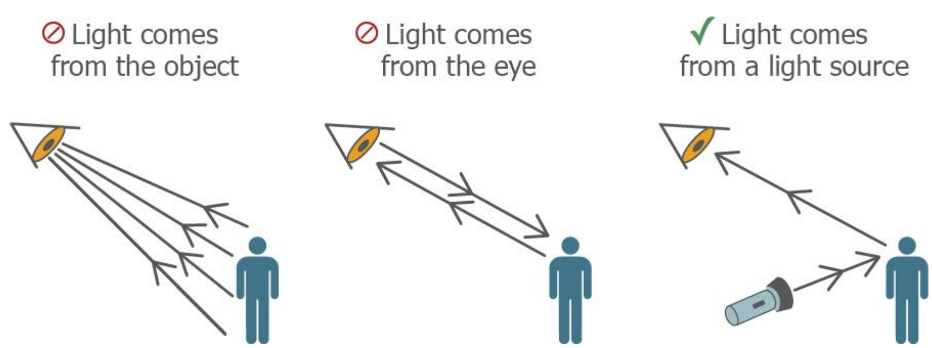
Draw lines of symmetry on different animals' faces, including humans. Discuss how the placement, size, and shape of eyes and ears on the head of each animal facilitate survival for prey species and for predator species in terms of sensing images and sounds. For example, predator species (cats) usually have eyes that are closer together for stereoscopic vision, while prey animals (horses) have eyes placed on the sides of their head to allow for a wider field of vision.

CA CCSSM: 4.G.3; MP. 2, 6

Models of How We See

Some observations of animal eyes can reinforce incorrect preconceptions about how sight works. A cat moving around in the night appears to have eyes that "glow." Is that how cats can see so well in the dark? In grade one, students made an argument that people require light to see (1-PS4-2). But what is the relationship between light and sight? Students can draw an initial **pictorial model [SEP-2]** that explains how they think we see objects (figure 4.17). To help students reassess their preconceptions, teachers can use science assessment probes such as "Apple in the Dark" and "Seeing the Light" (Keeley, Eberle, and Farrin 2005; Keeley 2012). "Apple in the Dark" asks, Would you be able to see a red apple in a totally dark room? "Seeing the Light" asks students to identify types of objects and materials that reflect light. Each probe asks students to identify what they know and to detail their thinking behind their choices. The student feedback from these formative assessments can help to direct the series of experiments and observations that follow.

Figure 4.17. Possible Student Models of How Light Enables Animals to See Objects



The model on the left is incomplete while the model in the center is largely incorrect. The model on the right shows light leaving a light source and reflecting off the person before it enters the eye.
Diagram by M. d'Alessio
Long description of Figure 4.17.

Collaborative student teams begin to investigate reflection with flashlights and mirrors. They conduct an **investigation [SEP-3]** by holding the flashlight at different angles and drawing diagrams representing their observations showing the trajectory of the light and indicating the source and the receiver of the light. They observe that light travels in a straight line away from the source and is then reflected. They investigate what happens when the light hits different surfaces including shiny surfaces (Mylar, glass, glossy paint) or objects (glass, crystal, leaves) and nonshiny surfaces (wood, dirt, eraser). Students performed similar investigations in grade one (1-PS4-3), but now they represent their results using **pictorial models [SEP-2]** showing the paths of light rays and using the language of angles to describe the reflections (4.MD.5). Students also relate the path of light to the movement of **energy [CCC-5]** (4-PS3-2). Students can draw a model of how light travels from the Sun and bounces off mirrors to the central tower of a concentrated solar power plant (linking back to renewable energy in IS2). Students may need to **obtain and evaluate additional information [SEP-8]** from articles and media to deepen their understanding of how light reflecting from objects and entering the eye allows objects to be seen. Students can develop posters that communicate their different models and explanations about vision. By conducting a gallery walk around all the posters, individuals can review and respond to the models developed by other students. Students can then apply their models to the original formative assessment probes about seeing in the dark (we cannot see without a light source) and what materials reflect light (all materials reflect some light or we would not be able to see them at all, but some materials reflect more light than others). They can gather additional information about why cats' eyes appear to glow (cat eyes have a unique internal structure like a curved mirror at the back of their eyes that causes light to reflect off the inside of their large eyes towards the eyes of a human observer). Students should then be able to **support the claim [SEP-7]** that one reason a cat can see well at night is because its eyes are large and therefore capture more of the light reflecting off of the objects they are viewing.

Sample Integration of Science and ELD Standards in the Classroom

Students notice that a car light shining on an animal at night reveals the animal's glowing eyes. To explain this phenomenon, students observe the structure and function of the human eye, and compare it to those of other organisms (4-LS1-1, 4-PS4-2). They create tables with brief descriptions that characterize the placement of each organism's eyes and the rationale for such placement (e.g., eyes located on the sides of their heads allow animals to see in front, to their sides, and behind them, helping them to be aware of predators).

CA ELD Standards: ELD.PI.4.10

Source: Lagunoff et al. 2015, 264–265

Internal Body Systems for Processing Information

Animals and plants have specialized structures that allow them to sense their environment. Animals collect information about environmental conditions (movement, temperature, color, sound) from the signals they receive through internal and **external structures [CCC-6]** or sense receptors (eyes, skin, ears, hairs, tongue, antennae). This information moves from the sensory receptors into the brain, where it is processed and used to guide the animal's actions, increasing its chances of survival. Every animal's brain is continuously receiving and responding to this sensory input from the environment.

Many of these sensory responses seem automatic. When a person suddenly pulls away from a hot object, what happens inside them to make this happen? Students record an initial model of what they think happens and then explore their own reactions to sensory input by experiencing hot or cold objects, the smell of perfume, or a special taste-testing paper called PTC. Students describe the sequence of events they observe in themselves and in other organisms. With the aid of informational media, they refine their **model [SEP-2]** of the systems that allow animals to sense and respond to their environment.

Grade Four Snapshot 4.5: Investigating Termite Sensory Systems

Anchoring phenomenon: Termites and other insects share many external body parts in common with one another.

Mr. S eagerly opened class with a question to activate his students' prior knowledge. He asked, "Have you ever seen termites before?" Anthony responds, "Last spring my parents had to call the termite people to clean the house. I didn't know we had termites. The whole house was covered in plastic for days." Mr. S responded, "Yes, termites sometimes make their homes in wooden houses. While it's a good place for the termites, it can weaken the house." He asked students what termites look like and some described them as "ants with wings" while others said they have seen termites without wings crawling out of rotting wood. He then asked, "What kind of animal is a termite?" Many students knew that termites are insects, so Mr. S asked them to draw as many pictures of insects as they could from their memory with as much detail as possible. Grouping students together in their usual teams with designated roles (facilitator, reporter, materials manager, and recorder), he asked students to compare their drawings and look for patterns in insect external **structures [CCC-6]**. "What body parts do insects have in common?" Students identified six legs, segmented bodies, wings, eyes, and antennae as common, though not universal, features of insect bodies. Mr. S asked, "Which of these body parts do you think a termite uses to sense its environment?" After some discussion, Mr. S told students that they would try to figure that out, and he pulled out a tray with several small containers. Something was moving in those containers!

Mr. S opened one container and projected a few termites on the screen with his document camera. He demonstrated how to be gentle with the termites and invited students to **ask questions [SEP-1]** about them, though he only answered background questions about them and deflected all questions that they might be able to investigate on their own. Then he said, "I am going to give each group a container with a few termites. Please, be gentle with them as I showed you earlier." The materials manager from each group quickly came to pick up a small container of termites, a pen, and a piece of paper.[2] He directed the recorder to draw a simple squiggle line on a piece of paper. The team facilitator then carefully poured the termites onto the paper while the remaining two students had small paintbrushes in hand to gently keep the termites on the paper. To the amazement of the students, the termites began to follow the pen design! Students recorded their observations and questions in their science notebooks.

2. If the teacher and/or school has concerns about students using live termites, the lesson can be adapted so only the teacher is responsible for handling the termites.

Grade Four Snapshot 4.5: Investigating Termite Sensory Systems

Investigative phenomenon: Termites follow a line drawn by a pen.

After several minutes of observations, groups generated a list of questions about what **caused [CCC-2]** the termites to follow the pen mark. Each reporter for the group shared in a whole-class discussion the list of questions and possible ideas that explained what **caused [CCC-2]** the termites to follow the pen mark: "We think the cause may be that termites follow a specific color, so I wonder if changing the color would make a difference in behavior." "Team four thinks the brand of pen determines the cause for the termites to follow the lines." "Can the termites follow different angle turns?" Other thoughts included placement of termites on the paper, the width of the pen, the odor of the pen, the texture that the pen made on the paper. Mr. S asked students to link each possible idea with a different sense organ on the termite and the **structures [CCC-6]** on the termite's body.

Investigative phenomenon: Termites follow lines drawn by some pens in certain shapes but not others.

Each team chose one variable or cause to test and examined and reported the result (effect) to the class. Mr. S helped each team create a table to record the data for its investigation; the table included the variable or cause the team was testing and the number of termites that followed the line drawn. They also recorded observations in their science notebooks. After careful **investigation [SEP-3]** and data recording, the groups carefully placed the termites back into their containers and prepared to share their experimental results with the rest of the class. Students found that termites followed the lines drawn by certain brands of pens. Ballpoint pens caused the most termites to follow the lines, and it did not matter if the design was curved or straight.

Color of writing implement	Trial 1-Curved Line # of termites following line	Trial 2-Curved Line # of termites following line
Blue sharpie		
Blue pencil		
Blue ballpoint		
Blue gel pen		

Mr. S. asked students to explain in their notebooks how they think the termites were processing the sensory information that allowed them to follow the trail. They were to include **evidence [SEP-7]** from their **investigations [SEP-3]** and describe a **cause and effect [CCC-2]** relationship. For several minutes the groups shared ideas and drawings.

Grade Four Snapshot 4.5: Investigating Termite Sensory Systems

Next, he provided students with background reading about how worker termites communicate with special chemicals called pheromones. Students **obtained information [SEP-8]** about how termites lay down these pheromones to communicate location of food or nesting locations. Termites' antennae are able to sense these pheromones and process this information in their brains, enabling them to travel to specific locations. Mr. S asked students to draw a concept map relating the ink in the pens to the termites' brains. These **pictorial models [SEP-2]** included components representing the termites' antennae, brains, and legs; the ink; and the connections between each of these concepts (4-LS1-2).

Mr. S asked students to review their concept maps and think about environmental changes they could make that would disrupt the movements of the termites. Several of the groups mentioned that using their finger to spread the ink might confuse the termites; others suggested that drawing many more lines of ink on the paper could also confuse them since they would not know which path to follow. Mr. S then related this mini activity on paper to human activities that change the environment in ways that disrupt the senses of the animals that live there, decreasing their chances for survival and reproduction (EP&C II). He asked the students to share ideas about how loud noises in a forest might affect songbirds. The groups developed and discussed their ideas, which they then shared with the class. Some of their ideas included the following: loud noises make it so that the birds could not hear each other's songs, and loud noises scare birds away from the area.

Advanced Information Processing

Sensory input also provides the basis for much more systematic communication. Humans use sound and sight to encode messages in language and music. Our ear receives the sound and our brain decodes it. We are not unique—many animals use sound to communicate with one another to warn of predators, to attract mates, to defend their territory, and more. Animal brains, like human ones, must learn to decode complicated messages in sound and sight.

Students used cameras as a model for vision because many probably have experience with how technology used in cameras collects and stores images. The digital screen itself is a light source that sends different colors of light directly to the eyes. But how does the device store the picture inside or transmit it across the world? Most of these devices use digitized signals (i.e., information encoded as series of 0s and 1s) as a reliable way to store and transmit information. Students can simulate the information-encoding process by developing their own Morse-code system to digitize short words and transmit them to another group of students using a flashlight or a drum.

Students could even develop a system to send an image across the room. They would start by drawing simple shapes on paper with grids and then convert that image into a digitized one by darkening only the squares that contain part of the original image (figure 4.18). Students can then agree upon a system for transmitting and communicating whether or not a square is filled or empty. The digitized image is rougher and "more edgy" than the original, but it is also easier for friends across the room to perfectly reproduce the exact same image. Students also recognize that if they use smaller squares, they can send a more detailed image, but it will also take longer to transmit. This activity is also a surprising manifestation of the CCC of **structure and function [CCC-6]** in engineering where the structured pattern of signals helps convey a message.

Figure 4.18. Practice Sample of Recreating Digitized Images

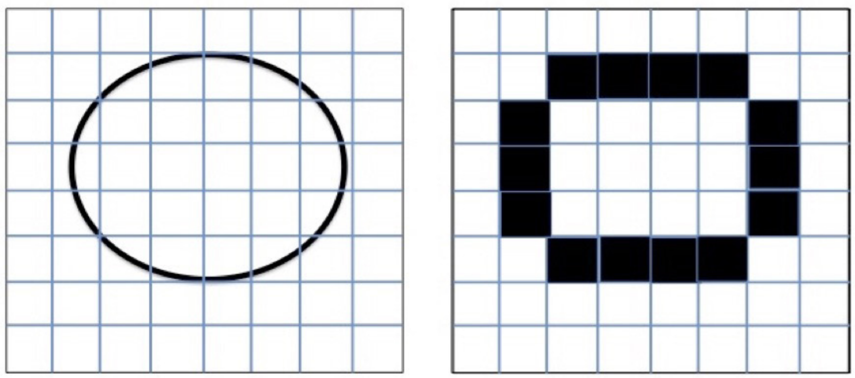


Diagram by M. d'Alessio
Long description of Figure 4.18.

Engineering Connection: Use Patterns to Communicate Information

Students can generate and compare multiple solutions that use **patterns [CCC 1]** to communicate information (4-PS4-3). For example, students can participate in a message-sending contest where each team must divide in two and send a message from one part of the team to the other part of the team around the corner of the building. An added challenge is that the message should not be recognized by any other team. Teachers remind students that they are going to use the engineering design cycle of defining the problem; identifying constraints; brainstorming to generate and compare multiple solutions that use patterns to transfer information; develop a prototype; test and refine. Teachers give them a variety of sound or light producing devices and materials to work with (e.g., mirrors). They then work in groups to develop **solutions [SEP-6]** for the problem and share their results with the class.

Opportunities for Mathematics Connections

Students encode messages using mathematical patterns as background knowledge, then relate these encoded messages to patterns in mathematics.

CA CCSSM: 4.OA.5, MP. 2, 4, 5

Sample Integration of Science and ELD Standards in the Classroom

When students are observing and explaining the phenomenon of energy transformations, they might begin by categorizing the varying forms of energy (light, sound, heat, electric current, mechanical, and chemical) and creating a list of existing examples for each, accessing experiential knowledge and language reservoirs (4-PS3-2). Ultimately, to emphasize energy transference from one place to another for the purposes of communication, students work in small groups to first construct a pictorial chart with the different forms of energy and then prepare a written report to generate, analyze, interpret, and describe multiple solutions that use patterns to transfer information (e.g., coded information through sound of drumming, Morse code, binary number encoding such as DVD and pricing tags, or simplified computer programming software/gaming) (4-PS4-3). The teacher leads students through analyzing a model for the written report, including examining key language features used in analysis and description. To support students at the Emerging and early Expanding level of English proficiency, the teacher pulls a small group and leads the students through jointly constructing the report, concentrating on the science content and vocabulary as well as the key language features studied in the model text.

CA ELD Standards: ELD.PI.4.10

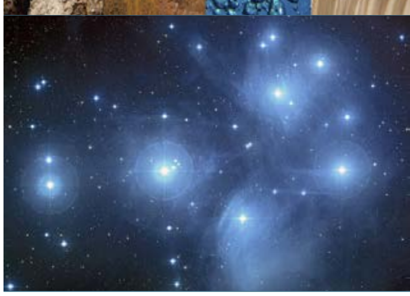
Source: Lagunoff et al. 2015, 264–265

Grade Five

As the culminating grade in elementary school, the entire year draws upon patterns and understandings developed in prior grades. Students look at phenomena from previous grades from the central theme of the exchange of **energy and matter [CCC-5]** within **systems [CCC-4]**. Table 4.4 shows a possible example of how instruction can be divided into instructional segments during grade five. The year progresses through systems of different **scales [CCC-3]** from tangible systems with chemicals in plastic zip bags in IS1 up to the scale of ecosystems in IS2 and then to the interacting subsystems of the entire planet in IS3. IS4 continues along this progression in terms of scale, but instead of tracking the flow of energy or matter within a system, it focuses on the input of energy *into* the Earth system from the Sun and other stars in the sky.

The entire year has an emphasis on **developing and applying models [SEP-2]**. In this framework, chapter 9 on assessment presents several strategies for formative assessment of students' models of systems. Using pictorial models like concept mapping allows students to represent their mental models and be very explicit about how the different components in the system interact and exchange energy and matter.

Table 4.4. Overview of Instructional Segments for Grade Five

	**1 What is Matter Made of?** Students observe different materials and describe their differences. They investigate how materials change when they mix together. They learn to recognize chemical reactions and develop a model of matter being made of particles. These particles move and their arrangement changes, but their mass always stays the same.
	**2 From Matter to Organisms** Students make models that trace the flow of energy and matter in ecosystems. They investigate the needs of plants and gather evidence that all organisms produce waste. They explain how animals depend upon one another as components in an interconnected system.
	**3 Interacting Earth Systems** Students make models of the flow of energy and matter at the scale of the entire planet, and obtain information about a few example phenomena. They describe these phenomena in terms of interactions between different systems within the broader Earth system. They use their models to understand how humans impact these systems and develop solutions to minimize these effects.
	**4 Patterns in the Night Sky** Students ask questions and wonder about the night sky. They investigate the force of gravity and then analyze data to identify patterns related to Earth's motion. They gather evidence and make models showing that the brightness of a star depends on its distance from Earth.

Source: Mesaros 2014; Owen-Wahl 2006; adapted from Schweihofer 2014; Deutsch 2012

IS1 Grade Five Instructional Segment 1: What is Matter Made of?

Grade five students delve into the most abstract scientific concept they have yet confronted, **developing and refining a model [SEP-2]** that describes matter as being made up of particles that are too small to see. By investigating a series of phenomena that emphasize the properties of materials and the **conservation of matter [CCC-5]** (the idea that material is not created or destroyed but just moves around within a system), students recognize that a model with matter as particles can explain many of the features they observe. This instructional segment has three main sections that progress from the observable down to the abstract: (1) describing materials; (2) mixing and changing materials; and (3) developing and applying a model of materials.

GRADE FIVE INSTRUCTIONAL SEGMENT 1: WHAT IS MATTER MADE OF?

Guiding Questions

- What causes different materials to have different properties?
- How do materials change when they dissolve, evaporate, melt, or mix together?
- What are the differences between solids, liquids, and gases?

Performance Expectations

Students who demonstrate understanding can do the following:

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen. [Clarification Statement: Examples of evidence supporting a model could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.] [*Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.*]

5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. [Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that forms new substances.] [*Assessment Boundary: Assessment does not include distinguishing mass and weight.*]

5-PS1-3. Make observations and measurements to identify materials based on their properties. [Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [*Assessment Boundary: Assessment does not include density or distinguishing mass and weight.*]

5-PS1-4. Conduct an investigation to determine whether the mixing of two or more substances results in new substances. [Clarification Statement: **Examples of combinations that do not produce new substances could include sand and water. Examples of combinations that do produce new substances could include baking soda and vinegar or milk and vinegar (CA).**]

GRADE FIVE INSTRUCTIONAL SEGMENT 1: WHAT IS MATTER MADE OF?

3–5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. [Clarification Statement: Examples of models could include diagrams, and flow charts.]

California clarification statements that are bolded and followed by **CA** *were incorporated by the California Science Expert Review Panel.*

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-4] Analyzing and Interpreting Data [SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-3] Scale, Proportion, and Quantity [CCC-4] Systems and System Models

Highlighted California Environmental Principles and Concepts:

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

CA CCSS Math Connections: 5.MD.3a, b; 5.MD.4

CA CCSS for ELA/Literacy Connections: SL.5.1, 4, 5

CA ELD Standards Connections: ELD.PI.5.1, 6

Engineering Connection: Selecting Appropriate Materials

Every material has specific properties. When students need to select the appropriate materials for an engineering challenge, their attention is drawn to these differences. This instructional segment can begin by providing students different materials and giving them the challenge to construct a tall tower that can bear a heavy mass. Which materials are best suited to the task? Students can devise techniques for measuring or quantifying many of these properties. How can students combine materials or modify their structure so that they work better? They can increase the strength of paper by rolling it into tubes, index cards by gluing them together with glue sticks, or spaghetti strands by taping several together. Testing the structures using a consistent procedure allows students to identify the specific mechanism of failure such as crushing and buckling, stretching and tearing (3–5-ETS1-3). Do different materials fail in different ways?

From everyday experience, students can recognize and name a wide variety of materials without even thinking about how they do it. Teachers need to make the implicit knowledge explicit, asking students how they know that one material is wood while another is stainless steel or aluminum. What properties can be used to describe a substance, classify it, and differentiate it from others? The most visible property, color, has only limited use because it can be changed with a thin layer of paint over a solid or drop of food coloring in a liquid. Instead, students learn to ask more detailed questions about materials. Students apply and expand the vocabulary they learned in grade two to describe material properties (2-PS1-1), but now they are ready to be more quantitative about their descriptions, making measurements of certain properties and using them to distinguish between materials (5-PS1-3). Making precise measurements can be motivated by the constraints considered when **defining engineering problems [SEP-1]**. For example, if we need to design a spoon that will not heat up more than 10 degrees when placed in boiling water, which material works best? Students can measure the heat conduction properties of several materials using a consistent test. Students can measure the melting temperature of different materials such as wax, chocolate, and ice to decide which material would make the best decorative sculpture for a summer birthday party. Students can measure the strength of different materials to determine which one to use to support a bridge that will bend without breaking when a toy car drives across it. Students can identify “mystery” powders based upon how much of each powder they can dissolve in a cup of water or how the powder reacts with various other ingredients.

To motivate the next section about physical and chemical changes to materials, students can think about all the properties that change when they mix materials to bake a cake (which can be done in class if permitted by school rules). Students can explain their thinking about the formative assessment probe: When you bake a cake, does the finished cake weigh more or less than the batter that you put in the oven? Does the batter weigh the same as all the raw ingredients separately? Many students explain that the cake dries out so it weighs less, but some may argue that it puffs up and so it weighs more. The question motivates a series of **investigations [SEP-3]** exploring how the mass of a material changes (or does not) under different conditions. Students can make qualitative comparisons using simple mechanical balances with cups or platforms on either side or make more precise measurements using calibrated triple-beam or digital balances. Students can work with the term *mass* rather than *weight* at this grade (the terms are used interchangeably in this instructional segment). Students can measure the mass of an object and then heat or cool it to see if its mass changes. Some materials get hot enough that they melt. Does melting or freezing change the mass of material?

When collecting real data, there is always the possibility that real-world factors will interfere with the intent of an investigation. In this case, precise measurements by scientists reveal no difference as a material is heated or cooled, melted or frozen—a given amount of material always has the same mass. If students use precise digital balances, they may observe small differences between their measurements that represent measurement errors or the effects of condensation and evaporation. Before making measurements, teachers will need to set up the comparison by having students make repeated measurements of the same object to establish how big a change needs to be observed before they can be confident that the change is real and not just the imprecision of the balance they are using. Similarly, they can emphasize the very large differences in properties between solids and liquids. Does the mass change as dramatically as the properties? Having students predict the **magnitude [CCC-3]** of differences ahead of time using this information gives them better context for **interpreting their data [SEP-4]**.

Next, students explore what happens when they mix substances together. How does mixing affect the properties and mass of the materials? Teachers give students substances to mix, some of which undergo chemical reactions and others that simply form mixtures. Students mix different combinations of mystery powders (such as baking soda, washing soda, flour, powdered lemonade, calcium chloride, corn starch, and Epsom salts) and liquids (water, vinegar, lemon juice, tincture of iodine, some mixed in with the juice from purple cabbage, which changes color as the pH changes) together in plastic zip bags and observe what happens (Sibenaller 2013). Some mixtures cause dramatic, unusual changes and reactions, while others are uneventful. Students should use their observations from before, during, and after mixing to support an **argument [SEP-7]** that a new substance formed (or did not form) when the powders and liquids were mixed together (5-PS1-4). They should notice patterns when certain groups of powders and liquids mix together and patterns in the types of unusual changes that can occur. Teachers can label these changes with the term *chemical reactions* and discuss the meaning of each of the two words. Common signs of chemical reactions are temperature changes (cold and hot packs), formation of a gas (effervescent tablet and water), color change (metal rusting), formation of a solid (stalactites and stalagmites/hard water build up), a change in smell (baking cookies or bread), and/or emission of light (glow stick). Students should be able to observe all of these (except glowing light) from their mixtures in the bags and should be able to describe how the properties of the new substance(s) are different from the properties of the original ingredients.

Clearly there are major changes inside some of the bags, but does the mass change? Students can measure the mass of the bags before, during, and after each reaction (5-PS1-2). In theory, the mass does not change even in bags that fizz and puff up with gas. Students can compare high-quality plastic zip bags with cheaper versions and see that some bags leak gas more than others (causing the mass to slowly drop as the fizzing progresses). This observation leads to an important and often unexpected discovery: gas has mass. Students can confirm this idea by comparing the mass of an empty balloon to the mass of one blown up with air (hanging the balloons on opposite ends of a meter stick, which can be used as a balance by hanging the meter stick from a string at its center). They can also confirm this by placing an empty cup on a balance, mixing chemicals that fizz in the cup, and watching the mass of the cup decrease as the reaction progresses. If they repeat this same reaction in a well-sealed bag, they will see that the mass stays constant. Based on their observations, students should be able to answer the original question about the mass of a cake and its ingredients—it may weigh less after cooking because some of the mass might have escaped into the air as a gas. The air in the room, however, would now weigh more (if you could measure it!).

While students have everyday experience with air as a gas, this is the first time that they explicitly explore the properties of gases in the California Next Generation Science Standards (CA NGSS). Students can explore different phenomena to characterize solids, liquids, and gases with the goal of describing and comparing their properties. How do we interact with each of the different states of matter (how do they look or feel)? Students investigated solids and liquids in grade two (2-PS2-1), so grade five emphasizes gases. Students can feel gases by moving their hand back and forth through the air or constructing windmills or parachutes to show how air exerts forces on objects. To probe students' initial **models [SEP-2]** of what gases are, teachers can have them hold a syringe filled with air and then draw and label what is inside the syringe (What would the air look like if you could see it under a microscope? How can you draw it?). Then, they hold their finger on the end of the syringe to trap the air inside and try to compress the plunger (they can make force diagrams using arrows like the diagrams in third grade 3-PS2-1). How does the air change? Students' initial ideas vary, but they can all be guided to recognize that the amount of air in the syringe does not change because it cannot escape (figure 4.19). But which of these models is correct?

Figure 4.19. Facsimiles of Students' Initial Models of Air

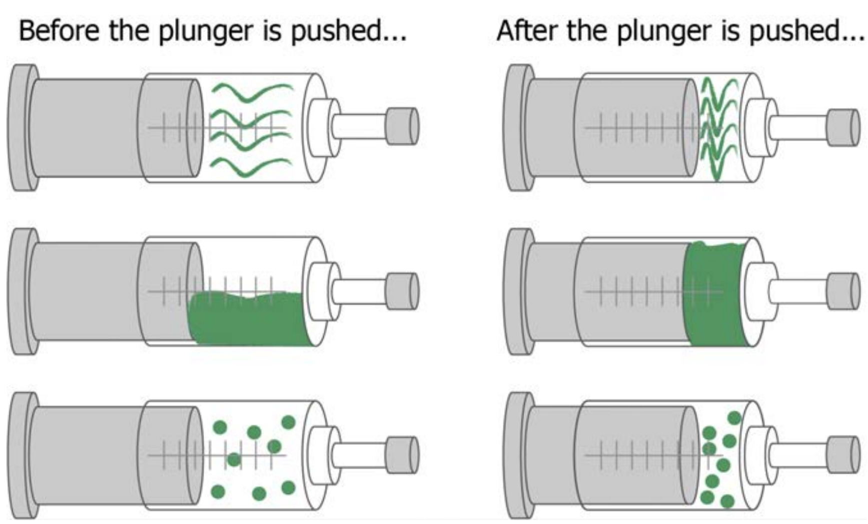
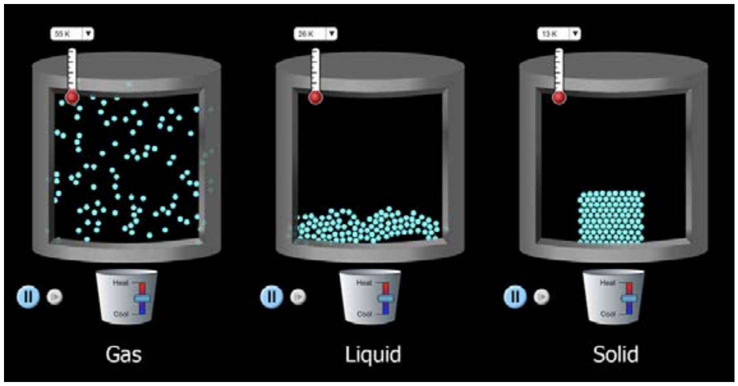


Illustration by M. d'Alessio
Long description of Figure 4.19.

Students correctly identify that the amount of material inside the syringe must be the same because nothing can escape. Students have different models of how that air looks or is distributed inside the syringe.

To distinguish between the different models, students can observe dust settling in a room or smoke from a match after it has been blown out. Video clips of these phenomena up close (try searching for "Dust, Brownian motion") reveal something interesting: even as the overall motion of the particles is a downward drift due to gravity, some of the particles suddenly move up. Students know from grade three that the only way to make something move upwards is to push or pull it upwards. What can be pushing the dust? The answer is that particles of air that are too tiny to see even with a microscope crash into the larger dust particles and alter their paths. Students then investigate computer simulations of matter that show a particle model of materials (figure 4.20).

Figure 4.20. Computer Simulation of Particles of Neon in Three States: Gas, Liquid, and Solid



Source: PhET n.d.c.
Long description of Figure 4.20.

Students can now return to all the different phenomena they have investigated in this instructional segment and look at them through the lens of the model. How do solids differ from liquids or gases? In the gas, there is so much empty space between the particles that we can often see right through it (which is why air is clear). In a solid, the particles are stacked in a defined structure and therefore are stronger and resist pushing and deforming more than liquids. How does the model explain the fact that mass stays the same even when you mix materials together, warm them up, cool them down, melt, or boil them? Each particle has its own mass, which does not change as the particles move around. Each of these processes involves changing the position and speed of the particles, but does not affect their mass. Students can draw a model of an empty balloon and one filled with air using this model and it becomes much easier to explain why the full balloon weighs more—there are more particles of air inside. They can draw a sugar cube dissolving in water by representing the cube as an array of stacked particles that disperse from one another when they enter the water. Each individual particle is too small to see, though collections of many particles together are visible. This leads to a discussion of the word disappear and its prefix (CA CCSS for ELA/Literacy RF.3.3a)—while particles can *disappear* (i.e., stop being visible), they do not go away or get destroyed. This concept of the conservation of matter is fundamental to all science. It also is the foundation of California's Environmental Principles and Concepts (EP&C) IV: "The exchange of matter between natural systems and human societies affects the long-term functioning of both." Pollution does not just go away, it ends up in air, water, soil, and in our bodies. Just as students are able to trace individual particles of sugar as they dissolve in water, scientists can follow particles of toxic pollution throughout waterways, in the air, and even into the human body.

This instructional segment emphasizes the evidence that builds up to a model and then the subsequent application of the model to explaining a wide variety of phenomena. Vocabulary is not a focus. At this grade level, the term *particle* is used generically for the scientific terms *atom* and *molecule* because the distinction between them is beyond grade five. Students need some names for the different types of particles in a mixture or solution (e.g., water particles, sugar particles, oxygen particles). However, the names of specific elements are introduced only as needed to describe and discuss their observations about matter-related phenomena, and the nature of the differences between different elements is not stressed.

GRADE FIVE VIGNETTE 4.3: PANCAKE ENGINEERING

Performance Expectations

Students who demonstrate understanding can do the following:

Students who demonstrate understanding can do the following:

5-PS1-4. Conduct an investigation to determine whether the mixing of two or more substances results in new substances. [Clarification Statement: **Examples of combinations that do not produce new substances could include sand and water. Examples of combinations that do produce new substances could include baking soda and vinegar or milk and vinegar (CA).**]

3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3–5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

California clarification statements that are bolded and followed by **CA** *were incorporated by the California Science Expert Review Panel.*

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-8] Obtaining, Evaluating, and Communicating Information	PS1.B Chemical Reactions ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and System Models

CA CCSS Math Connections: 5.MD.3, 5.MD.4

CA CCSS for ELA/Literacy Connections: SL.5.1.a-d

CA ELD Standards Connections: ELD.PI.1, 3, 9

GRADE FIVE VIGNETTE 4.3: PANCAKE ENGINEERING

Introduction

What does cooking have to do with engineering? What effects do certain ingredients have on others? Mixing pancake batter creates a chemical system with interacting components, and each ingredient plays a different role within the system. This fifth-grade activity merges scientific understanding of chemical reactions and systems with an engineering design challenge to make the perfect pancake.

Day 1: Define Criteria

What does a perfect pancake look like?

Students come up with the criteria for their ideal pancake: golden brown, fluffy, and tasty.

Day 2: Plan Solutions

What happens when we mix two materials?

Students investigate what happens when two ingredients are mixed together in order to understand the behavior of different ingredients. They vary proportions and identify trends. Finally, students try cooking their pancakes and discover something is missing.

Day 3: Create, Evaluate, and Improve

What is the optimal proportion of ingredients?

Students spend the lesson mixing ingredients, cooking the pancakes, evaluating the results, and making modifications to achieve their ideal pancake.

Day 4: Communicate Results

What changes did I make?

Students create a summary document explaining what they changed from one trial to the next. The class then compares recipes from the "best" pancakes to find patterns. Students then decide on three recipes to try to repeat and see if the results are the same.

Day 1: Defining Criteria

Everyday phenomenon: Pancakes are fluffy, golden brown, and tasty.

Mrs. C always told her students that "engineering is everywhere!" In this activity, students engineered the "perfect pancake." Mrs. C assigned six students to read parts from a script where they played the roles of students waiting for their food at a pancake restaurant. The characters argued about whether they liked their pancakes fluffy or thin and described the "secret recipes" used in their houses. Mrs. C showed a diagram of the stages of the engineering design process and asked students to discuss how different lines from the script related to stages in the process. In order for Mrs. C's students to design the perfect pancake, they needed to **define the problem [SEP-1]** by specifying the criteria (3–5-ETS1-1). How would they decide if they had succeeded? The class decided that the pancakes should be golden brown, fluffy, and tasty. But how would they measure these properties? For golden brown, the students decided that they could compare their pancake to a color palette that

GRADE FIVE VIGNETTE 4.3: PANCAKE ENGINEERING

shows different shades of brown and agree on a particular shade that they consider "ideal." A "fluffy" pancake should rise tall; students decided to measure the pancake height by sticking a toothpick in the center and seeing how deep it went by holding a ruler next to it. The last criterion of "tasty" is subjective. Unlike science, which strives to be completely objective, engineering deals with designing solutions that meet people's needs and desires. The engineers that design a car, for example, pay as much attention to the car's appearance as they do to its mechanical systems. Even though the criteria were subjective, students still needed a way to track and record their opinions. They decided to rate the tastiness of the pancake using a one to five star scale.

Day 2: Planning Solutions

Investigative phenomenon: The properties of batter depend on how much flour, baking powder, and water are combined.

Students did not get a recipe to follow—they used a design process to eventually determine an ideal combination of ingredients. As in many design problems, students needed to gather information about the materials available to them to plan their solution. Mrs. C provided students whole-wheat flour, oat flour, water, and baking powder. Students chose two different ingredients to mix together and saw what happened. Baking powder and water fizz, water and flour turn into thick dough, and baking powder and flour seem unchanged by their interaction. Different students tested out different relative proportions of the ingredients and described their results to the class so that they could identify **trends or patterns [CCC-1]** (figure 4.21). Mrs. C emphasized that it is important that students measure carefully so that they can make meaningful comparisons between one recipe and another. To facilitate comparisons, Mrs. C added the constraint (part of **defining the problem [SEP-1]**) that every pancake must always use exactly one scoop of flour. Students could vary the other ingredients, but the flour had to remain constant. Students noticed that more baking powder caused more fizzing and that wheat flour seemed to make thicker mixtures than oat flour when combined with identical amounts of water. After exploring the interactions, students observed what happens when different proportions were used. Mrs. C described a pancake recipe as a chemical **system [CCC-4]**. The ingredients were components of the system and the day's tests characterized different interactions between the components when they were in simple two-ingredient systems. Students combined these ideas into a **model [SEP-2]** of the full system as they adjusted their recipes in the upcoming part of the lesson. Groups of students used their observations of the simple systems to decide the proportions of each ingredient to use for their first test pancake. Their discussions were simple **arguments supported by observational evidence [SEP-7]**: "I think we should use two parts water to one part flour because the batter was too thick in the 1:1 mixture." Mrs. C helped students cook their one test pancake on the griddle.

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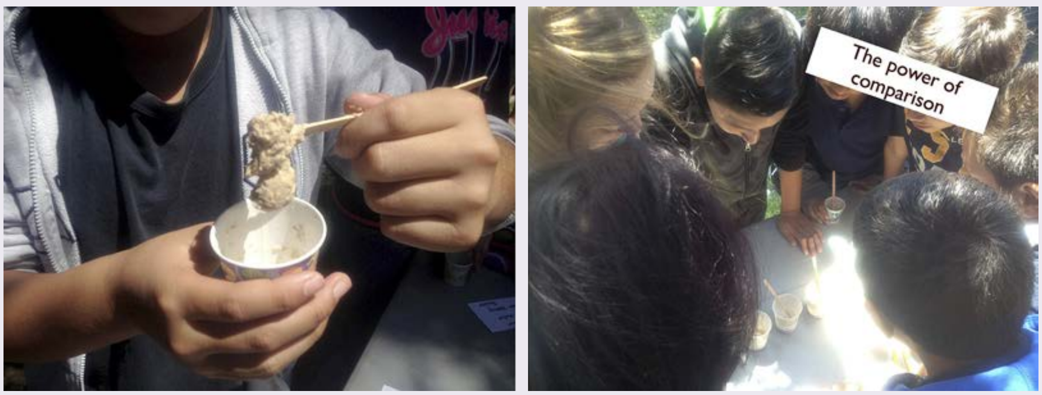
Investigative phenomenon: None of the pancakes turn brown.

Watching the pancakes cook, every group decided its test pancake was a “failure” because none turned brown! What could be missing from the system? Students measured the thickness, compared the white pancakes to the color chart, and recorded the results on a data sheet. Mrs. C told students real engineers get excited when their design fails because it gives them the opportunity to learn more about the system and to try again.

Figure 4.21. Students Compare Different Batter Recipes



Long description of Figure 4.21.

Day 3: Create, Evaluate, and Improve

Investigative phenomenon: What combination of ingredients will produce the perfect pancake?

Mrs. C wanted students to experience the power of the iterative process of engineering. Clearly something was missing from their previous pancakes, so Mrs. C offered two additional ingredients today: pureed bananas (one banana and one-quarter cup water pureed in a blender) and vanilla extract. Students began the lesson by mixing ingredients using the knowledge they gained about each ingredient in the prior lesson and adding the new ingredients. Parent volunteers helped students cook their pancakes and evaluate the results (there were four cooking stations set up in different corners of the classroom). How fluffy was it? Was it golden brown? How did it taste? Mrs. C reminded the students to carefully write down the proportions they used after each attempt so that they could systematically change ingredients or proportions to get better results. One student added a lot of vanilla (“because it’s brown”), but his pancake still did not turn brown. Another student used banana puree instead of water (“I love bananas”) and her pancake was the first to turn a beautiful golden brown.

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Soon, students were experimenting with different proportions of banana and water (figure 4.22). Mrs. C circulated while the pancakes were cooking, asking students to apply their mental model about the role of each ingredient by asking things such as, Looking at these two pancakes, which one do you think has more baking powder? Do you think that this pancake has any banana in it? How can you tell? Wow, that pancake is really thin. What do you think you could add to improve it? Based on their discoveries and comparisons with peers, students made modifications to achieve their perfect pancake. Students enjoyed eating their successes!

Figure 4.22. Students Systematically Test Different Recipes

(Amount used in teaspoons)				
Water	2	1.5	1	0
Banana puree	0	0.5	1	2

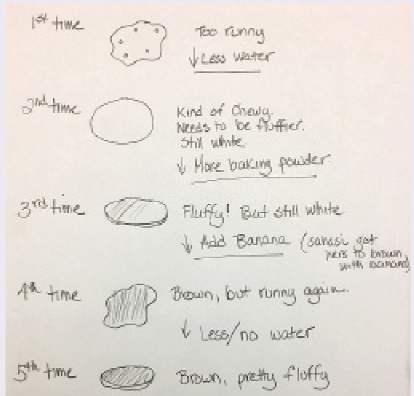
Long description of Figure 4.22.

Day 4: Communicating Results

During day 3, students carefully documented their ingredients and results. This day, Mrs. C asked them to reflect on the sequence of mixtures they used. The students made a "storyboard" showing the succession of pancakes (figure 4.23). For each frame, the students described in words how the pancake turned out. Mrs. C asked students to draw arrows between the frames describing what they changed and why they made that change from one trial to the next.

GRADE FIVE VIGNETTE 4.3: PANCAKE ENGINEERING

Figure 4.23. Student's Storyboard Documenting Recipe Refinement



Long description of Figure 4.23.

After they finished writing, the students compared all of the recipes and picked the best three that they wanted to try to repeat as a class (3–5-ETS1-2). During the discussion, students had to **support their choice with evidence [SEP-7]** from the recorded results. Mrs. C cooked the pancakes and one recipe turned out very different than on the previous day. Students discussed in groups why they think it might have been different and came up with ideas about mistakes in measuring ingredients and mistakes in recording the results. Mrs. C emphasized that careful measurements and documentation are essential skills that allow professional engineers to reproduce their solutions and share them with others.

Mrs. C wanted students to discuss how pancake cooking relates to chemical reactions. She reminded students that a chemical reaction could change the way substances look, smell, feel, or taste. She told them that there were at least three key chemical reactions that they could identify from the ingredient mixing and pancake cooking lessons. She instructed students to work in groups to fill in a table describing three different chemical reactions and how they recognize them (table 4.5).

Table 4.5 Chemical Reactions in Pancakes

blank	Evidence for chemical reaction	Which ingredients reacted?	How did you determine which ingredients reacted?
1	Batter consistency/texture changes	Flour & Water	Happened when we combined flour & water alone in Lesson 3 (the texture change is more dramatic in wheat flour than oat flour).
2	"Fluffing": Bubbles form in batter (and more bubbles form when temperature goes up).	Baking powder & Water	Baking powder fizzed when mixed with water in Lesson 3.
3	"Browning": Unusual color change on outside of pancakes.	Banana & ???	Only happened when we added banana.

GRADE FIVE VIGNETTE 4.3: PANCAKE ENGINEERING

Vignette Debrief

SEPs. Students performed a complete engineering design process that employed a wide range of SEPs. They began by **defining the problem [SEP-1]** as they developed criteria for making the perfect pancake (3–5-ETS1-1). They **conducted investigations [SEP-3]** into what happened when they mixed the available ingredients and again when they cooked their pancakes and recorded the results. They **asked a question [SEP-1]** at the end of day 2 when they discovered that all their pancakes were white: "What are we missing?" This question motivated a change. They briefly engaged in **arguments supported by evidence [SEP-7]** when they worked with teammates to select proportions to test on days 3 and 4, though this practice was not a major focus of the vignette. They iteratively **designed a solution [SEP-6]** as they tried out different proportions of ingredients to hone in on the perfect combination (3–5-ETS1-2, 3–5-ETS1-3). The changes they made were based on a **mental model [SEP-2]** of the chemical system and how each ingredient affected the system's behavior. They **analyzed and interpreted their data [SEP-4]** by reflecting on how their design changed from iteration to iteration on day 4. Teachers could extend the lesson to include more **mathematical thinking [SEP-5]** by having students graph pancake thickness versus amount of water, or help them **communicate their findings [SEP-8]** by creating a cookbook that also explained the science behind pancakes.

DCIs. By discussing the physical properties of the raw ingredients, the batter, and the cooked pancakes, students could gain a better understanding of the structure and properties of matter (PS1.A). The table on day 4 makes an explicit tie to chemical reactions (PS1.B). PS1.B does not occur in the foundation box for 5-PS1-4 in CA NGSS but is a focus in the middle grades (MS-PS1-2). The motivation for including it here is that explicit instruction about the observable features of chemical reactions draws attention to the types of changes that can occur in substances. However, the discussion of chemical reactions should be limited to observations with the naked eye or other senses. In the middle grades, students learn to relate these observable changes to a model of interacting molecules, but that discussion is not part of fifth grade in the CA NGSS.

CCCs. The CCCs helped draw students' attention to the physical processes at work. There was major emphasis on **scale, proportion and quantity [CCC 3]** throughout the ingredient exploration. Students thought about their recipe as a chemical **system [CCC-4]** that had components (ingredients) and energy input (heat from the griddle). They adjusted the amount of each ingredient, which **caused different effects [CCC-2]** on the pancake system (including the system properties of how it looks and tastes). The entire lesson sequence could be thought of as one large investigation into how the mixing of substances can cause changes that create a new substance (5-PS1-4).

CA CCSS Connections to English Language Arts and Mathematics. Throughout the lesson sequence students participated in collaborative conversations with their classmates to engineer the perfect pancake (SL.5.1a-d). This process called for students to measure and combine various ingredients and carefully record these measurements (5.MD.3-4). Through trial and error the students combined the different ingredients in different quantities until they create the perfect pancake.

GRADE FIVE VIGNETTE 4.3: PANCAKE ENGINEERING

Resources:

Lesson plans with further guidance are available at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link14

Sources:

Pictures and figures courtesy of Holliston Coleman and Matthew d'Alessio, California State University, Northridge.

IS2

Grade Five Instructional Segment 2: From Matter to Organisms

Prior to reaching grade five, students have developed understanding of the DCIs that all animals need food in order to live and grow; that they obtain their food from plants or from other animals; and that plants need air, water, and light to live and grow. Now, students tie all these ideas together with a **model [SEP 2]** that describes how **energy and matter flow [CCC-5]** within a **system [CCC-4]**. They trace matter from nonliving sources (water and air), to plants, animals, decomposers, and back again to plants. They also use their models and look for evidence to describe how **energy flows [CCC-5]** from the Sun to plants to animals.

GRADE FIVE INSTRUCTIONAL SEGMENT 2: FROM MATTER TO ORGANISMS

Guiding Questions

- What matter do plants need to grow?
- How does matter move within an ecosystem?
- How does energy move within an ecosystem?

Performance Expectations

Students who demonstrate understanding can do the following:

5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water. [Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.]

5-LS2-1. Develop a model to describe the movement of matter among plants, animals decomposers, and the environment. [Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [*Assessment Boundary: Assessment does not include molecular explanations.*]

5-PS3-1. Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the Sun. [Clarification Statement: Examples of models could include diagrams, and flow charts.]

GRADE FIVE INSTRUCTIONAL SEGMENT 2: FROM MATTER TO ORGANISMS

5-ESS2-1. Develop a model using an example to describe ways in which the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: The geosphere, hydrosphere (including ice), atmosphere, and biosphere are each a system and each system is a part of the whole Earth System. Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*] (Introduced but not assessed until IS3)

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS1.C: Organization for Matter and Energy Flow in Organisms LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems PS3.D: Energy in Chemical Processes and Everyday Life ESS2.A: Earth Materials and Systems	[CCC-5] Energy and Matter: Flows, Cycles, and Conservation

Highlighted California Environmental Principles and Concepts:

Principle I The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

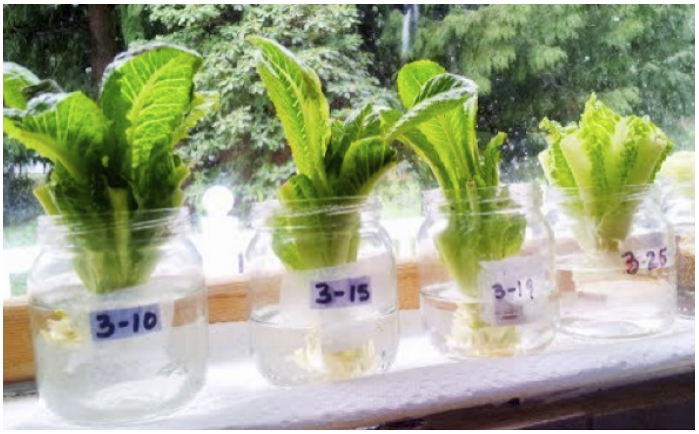
Principle V Decisions affecting resources and natural systems are complex and involve many factors.

CA CCSS for ELA/Literacy Connections: W.5.1, SL.5.4, 6; L.5.6

CA ELD Standards Connections: ELD.PI.5.1, 3, 9, 11, 12

Students have specifically investigated the needs of plants in kindergarten and grade two. Teachers can probe their students' existing ideas about plants by asking students to provide evidence that makes them **agree or disagree with the claim [SEP-7]**, "Plants can grow without soil." Students can directly investigate the question by trying to germinate and grow seeds in a medium of wet paper towels (inside a CD case so that they can watch the process). They can also try to regrow lettuce, celery, or other plants in water alone by placing the bottom section of a head of lettuce into a cup of water (figure 4.24). Students can track the mass of the plant and the mass of the water they add.

Figure 4.24. Lettuce Growing Without Soil



Source: Misilla 2014
Long description of Figure 4.24.

One of the first scientists to test out similar ideas was Jan Baptist van Helmont in the 1600s. He took about 5 kilograms (kg) of dry soil, put it in a pot, added water, and planted a tree in the soil. After a year the tree had gained about 1 kg of mass. Van Helmont carefully dried the soil and weighed it again. He was surprised to discover that the mass of the soil was still about 5 kg (figure 4.25). The result must have been very confusing. As the plant builds its body, the raw materials for making wood, leaves, bark must come from *somewhere* and the soil seems to be the most likely source. But his experiment showed otherwise. Where does the mass in plants come from? It must come from one or both of the plant's other needs for matter, air, and water. By tracking the amount of water in their own experiments, students may be able to figure out the answer. Unfortunately, the experiment is quite challenging to do precisely because water evaporates so easily. Could students design an experiment to figure out the contributions to the plant's mass that would be better than either van Helmont's or their own? Students will revisit this concept again in the middle grades when they develop a model of the chemical reactions by which atoms are rearranged from air and water molecules and transformed into plant molecules (MS-LS1-7).

Figure 4.25. Van Helmont's Experiment

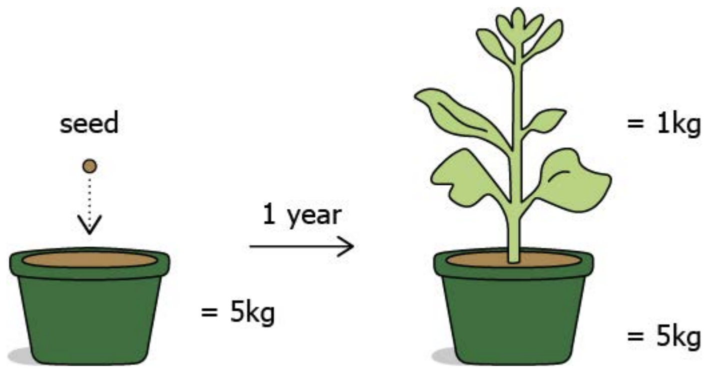


Diagram by Ed Himelblau.
Long description of Figure 4.25.

During the days that it takes the seeds and lettuce to germinate and grow, students can perform other simple **investigations [SEP-3]** to track the **flow of matter [CCC-5]** into plants. They can place celery or flowers in colored water to see transportation of water into the celery or flower, or try to grow a plant in a closed container with no airflow into the container. As they add their own measurements from seeds and plants grown in water alone, students should have enough evidence to construct an argument that plants get the materials they need to grow primarily from air and water (5-LS1-1). At grade five, students do not distinguish components of air such as oxygen and carbon dioxide but can describe the gases generally as air. Carbon dioxide in the air is a key ingredient in photosynthesis, a process used by plants to convert energy from the Sun into a form they can use to grow and reproduce. The DCI progressions from appendix 1 of this framework do not introduce the term *photosynthesis* until the middle grades. The rationale for this delay is to wait until the specific chemical process is introduced before giving it a label.

Since plants can survive with only air and water, can people? Students observed in kindergarten that all animals require food (K-LS1-1) because animals lack the ability to directly convert sunlight energy into usable energy. The next section explores the interdependence of animals and plants.

Plants within Ecosystems

Students constructed arguments that organisms interact with their environment in grade three (3-LS4-3). Now, students examine these dependencies in terms of the flow of energy and matter. There is no clearer illustration of the interdependence of organisms than a sealed glass sphere (figure 4.26) containing algae, brine shrimp, some air and water. If plants consume air and water resources from their environment, how can they continue to survive in the sealed sphere? Won't they run out of air? They would not survive alone, but the entire system can persist because the organisms exchange matter back and forth with one another. A system in which organisms interact and exchange matter and energy with each other and their environment is called an ecosystem.

Figure 4.26. A Sealed Glass Pod Contains an Entire Ecosystem

Source: Ecosphere Associates Inc. 2013
Long description of Figure 4.26.

As animals eat plants, they consume all the matter in the plants. They can use this matter as raw material for growing their own body, and they can metabolize it to convert it into usable energy. The same process occurs when animals eat other animals. Tracking which animals eat one another allows students to create a model of how energy and matter flow in an ecosystem. This **model [SEP-2]** is called a *food web*. Students can construct food webs by making direct observations about what animals consume. Observations can be in small classroom ecosystems such as a terrarium or fish tank or, whenever possible, students should take field trips to observe plants and animals in more natural conditions (including urban environments like parks as well as nature centers and outdoor schools).

Students can draw a food web for the visible organisms in the sealed spheroid ecosystem of figure 4.26—a very simple diagram showing brine shrimp eating algae. This relationship benefits the shrimp, but it does not explain how the algae (plants) continue to survive as they consume all the air in the sealed container. A food web is not a complete model of the flow of matter in an ecosystem. The algae transform energy from the light entering the ecosphere, and all of the organisms, including plants, give off waste.

To extend their models, students can investigate some of the waste products produced by plants. When students place a plastic bag over the leaves of a plant, the inside of the bag gets wet revealing that the plant gives off water. When they submerge Anacharis, Elodea, or rosemary plants in water, they observe tiny bubbles of gas released from the leaves. Students can measure the quantity of gas by counting bubbles or trapping the gas in an inverted test tube placed over the plant, recognizing that the rate of gas release depends on the amount of light shining on the plant. Is the gas that plants take in the same as the gas they release? Unfortunately, students do not have the tools to distinguish between these gases. They will have to wait to the middle grades to answer this question. Even without this information, students should be able to **explain [SEP-6]** that plants obtain matter as gases and water from the environment and release waste matter (gas, liquid, or solid) back into the environment (5-LS2-1). Similarly, they can integrate their own waste products into the model.

Because decomposers are often not visible, few people are aware that decomposers play a very important role in the flow of matter and energy through ecosystems. Students can view a sample of the water (or at least a photograph or video of it) from a local pond, stream, or even a drainage ditch, under a powerful microscope (with magnification of at least 400x) and see tiny bacteria floating around. What do they eat? How do they fit into the model of energy and matter flow? Students discuss the possibilities and come up with four options: (1) they get energy from the Sun like plants; (2) they eat the algae; (3) they eat the brine shrimp; and (4) they eat the waste given off by the other organisms. They rule out the possibility that the bacteria eat the brine shrimp because the shrimp are still alive. Students must **obtain information [SEP-8]** to learn more about bacteria in order to choose from among the remaining options. While some single-celled organisms get energy from the Sun, bacteria do not. Many bacteria eat the waste from other organisms. Many bacteria live inside the human intestine and eat parts of our food that we cannot digest by ourselves. When organisms die, the matter and nutrients that they have accumulated over their lifetime remain trapped in their body.

Decomposition is the process that releases the energy and nutrients from dead tissue for use by growing organisms. Decomposers can be both microscopic (bacteria) and easily visible (fungi and mold), but they all do the same thing: they consume plant and animal bodies, releasing energy and nutrients in a form that makes them more readily accessible to other organisms. Without decomposers, dead plants and animals and their waste products would accumulate in ecosystems and the energy and matter they contain would not be available to other organisms. Students add decomposers into their ecosystem models.

Grade Five Snapshot 4.6: Cycles of Decomposition

Anchoring phenomenon: At a nature center, a wide variety of plants and animals live together.

Ms. D has coordinated with the staff at a local nature center, and they have identified a specific area where the class can **investigate [SEP-3]** food webs and observe an area where decomposition is an active process. On the day of the field trip, the nature center staff helped students identify several different producers and consumers. As students discovered what lives in the area, they worked together to create and discuss a food web.

Everyday phenomenon: Plants and animals die.

Ms. D then asked, “What happens when one of the plants or animals in the food web dies?” The students looked around for evidence of decomposition nearby. They identified fallen leaves, a rotting tree trunk, and a dead insect on the ground.

Investigative phenomenon: The layer of leaves on the ground probably only took a few years to accumulate, but the tree has been growing for decades. (Where did all the other leaves go?)

Ms. D asked the students how long they think it took for all the dead leaves to fall on the ground, and the students estimated several years. Ms. D then pointed to the tree and said, “but this tree has been here for a hundred years. What happened to all the leaves that fell before?” While some students suggested that the wind blew them away, Ms. D asked them to look more closely at the leaves on the ground and the other dead objects. She then led them through a discussion about how the tree trunk, leaves, and animals are breaking down and reentering the soil.

When they returned to the classroom after the field trip, Ms. D had them read an informational text about some of the organisms involved in decomposition and how they relate to the rest of the ecosystem (see “Decomposition in the Forest” at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link15, p. 12).

Investigative phenomenon: Dead material seems to progressively break down.

She then projected different examples of decomposition in action (see “Evidence of Decomposition” at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link16, pp. 2–4) and asked the students to describe what they saw. In each case, Ms. D asked students where the matter

Grade Five Snapshot 4.6: Cycles of Decomposition

came from and what happened to it after it decomposed. She emphasized that when matter decomposes, it may seem to disappear, but it is actually moving into a different part of the ecosystem releasing nutrients back into the soil, air, or water. To help the students practice **constructing explanations [SEP-6]** of the decomposition process, she distributed a drawing with a sequence of events that relate to decomposition (leaves fall, worm eats leaves, worm feces fertilize soil, bird eats worm, etc.) (See *Breaking it Down—In the Forest* at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link17, p. 13). Students wrote brief descriptions about each step and how it relates to the **flow of energy or matter [CCC-5]** in the ecosystem.

Ms. D led a class discussion about the picture and asked students if they noticed any patterns in the sequence of events. Several of the students commented that the drawing shows the matter flowing among plants, animals, and microbes as these organisms live and die. She asked, "Does this **flow of matter [CCC-5]** occur only once or is it an ongoing process?" and led the class in a discussion that helped students recognize that the **flow of matter [CCC-5]** in the diagram is an example of a **cycle [CCC-5]**. She then wrote a definition for the word *cycle* on the board, "a series of processes or events that typically repeats itself."

To help students recognize the importance of matter moving through ecosystems among plants, animals, and decomposers, Ms. D asked them, "What would happen if the cycle of matter flowing through ecosystems is interrupted by human activities?" This allowed the students to begin building an understanding that human activities can affect "the exchange of matter between natural systems and human societies affects the long-term functioning of both" (EP&C IV).

Ms. D asked students to reflect on how decomposition is important to them, strengthening their understanding that the ecosystem services provided by natural systems are essential to human life, including what we eat, the plants we can grow and the overall functioning of our economies and cultures (EP&C I).

Everyday phenomenon: Compost turns food waste into soil.

Several students mentioned that the decomposition process is related to the compost pile that the class has been managing near their school garden. Some of the others discussed that they were surprised that by composting at home, they were keeping most of the plant materials from their meals and yards from going into the landfill and they thought that their gardens benefited from the nutrients in the compost.

Resources

California Education and the Environment Initiative. 2013. *Breaking it Down—In the Forest*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link18.

———2013. *Decomposition in the Forest*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link19.

———2013. *Evidence of Decomposition*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link20.

While students collected evidence that plants can grow for at least some time without soil, plants acquire some essential materials from the soil. Nitrogen, iron, and many other nutrients must be obtained from the soil (usually by the roots) because plants cannot survive without these. These nutrients, however, make up only a small fraction of the total mass of a plant. If van Helmont had had a sensitive enough scale he might have detected a tiny decrease in the mass of his soil. Again, plants provide a means for animals to get many of the nutrients they need. For example, animals need very tiny amounts of metals like iron, zinc, and magnesium to survive, but they cannot get all the nutrients they need by just eating soil. To take these nutrients into their cells, the nutrients need to be incorporated into more complex molecules (sometimes called *vitamins*). These complex molecules are synthesized in plants. Plants, on the other hand, are able to absorb individual metal atoms from the soil surrounding their roots. Animals consume these nutrients when they eat plants, or eat other animals that have previously eaten plants. Students integrate this information into their model. How will they represent the fact that nutrients are only a tiny fraction of the plant's mass yet are important for plant growth and survival?

Students must now reflect on their models of ecosystems and develop ways to represent and **communicate [SEP-8]** them. They could play games (physical or kinesthetic models) where primary producers receive energy from the Sun, use some for growth and respiration and pass the rest to primary consumers and so on. The assessment chapter of this framework (chapter 9) includes a snapshot demonstrating how students can use a pictorial model generated on a computer to represent the energy flow in an ecosystem. They should be able to use their model to explain how the energy animals use to grow and survive originated as energy from the Sun (5-PS3-1).

This instructional segment reflects one of the key instructional shifts of the CA NGSS with a focus on the SEPs that require developing and refining models. Rather than having teachers present students with a model of ecosystems and defining the vocabulary terms of producers, consumers, and decomposers as components of the system, students began with an incomplete model. As they explored different phenomena, they progressively revised and extended their model to include additional exchanges of matter. The model students have at the end of grade five is by no means complete—they will revise it in the middle grades and again in high school. Despite the fact that this research began in the 1600s with van Helmont, professional scientists are continuing to refine the models of mechanisms and relationships within ecosystems. As teachers focus on **developing and using models [SEP-2]**, students will gain useful insight into the nature of science as well as construct their own understanding of DCIs about ecosystems.

Sample Integration of Science and ELD Standards in the Classroom

Students have observed, through pictures and simulations, some representations of the movement of matter within ecosystems. Working in small groups, the students build on those experiences by using their science texts and notes as they collaboratively construct their models of how matter moves within ecosystems. Each group constructs an argument about its model, focusing on the movement of matter among plants, animals, decomposers, and the environment. Each group shares its model with another group, while the other group provides feedback based on the following co-constructed criteria: 1) presentation effectiveness, 2) the types of materials and representations use, and 3) whether the cycling of matter is accurate (5-LS2-1). During their conversations, the students refer to a large chart on the classroom wall that contains options for different language purposes, such as entering a conversation (e.g., One/another piece of evidence that supports our argument is ___.); agreeing and disagreeing (e.g., I can see your design has ___; however, ___.); or elaborating on an idea (e.g., That's a good choice for ___, and I'd like to add that ___.). To support students at the Emerging level of English proficiency, the teacher asks each group to practice what each member of the group will share, and no member was permitted to opt out. The teacher had created heterogeneous groups, ensuring that each student at the Emerging level of English proficiency had a "language buddy" who was proficient in both English and the student's home language. The teacher had also created a supportive environment so that students worked together to make sure that each student understood and could communicate that understanding.

CA ELD Standards: ELD.PI.4.3
Source: Lagunoff et al. 2015, 248–249

Sample Integration of Science and ELD Standards in the Classroom

Students who are working in small groups to create models about the cycling of matter in ecosystems provide feedback to their peers, using appropriate verb tenses (e.g., "At first, the arrows you drew were pointing toward the soil. Now you have changed them, so I understand that materials from the water and air go into the plant.") (5-LS2-1). The teacher provides verbal support to students at the Emerging level of English proficiency by highlighting specific verb tenses for specific purposes in texts and speech.

CA ELD Standards: ELD.PI.4.3
Source: Lagunoff et al. 2015, 275–276

IS3

Grade Five Instructional Segment 3: Interacting Earth Systems

Scientists have developed a way of thinking about the Earth as a system of systems (much like the human body is a system of systems). A system has internal components that interact with one another (like the water cycle on Earth or the nervous system in a human body), and a system also interacts with its surroundings (like when water in the water cycle causes a flood or when the nervous system causes a muscle to move). In this instructional segment students explore each of Earth's systems and how they work together to explain various phenomena. They then obtain information about the role of humans in altering natural interactions. Students finish with action plans about what they and their community can do to minimize the effects on humans and the impact of human activities on natural systems.

GRADE FIVE INSTRUCTIONAL SEGMENT 3: INTERACTING EARTH SYSTEMS

Guiding Questions

- How can we represent systems as complicated as the entire planet?
- Where does my tap water come from and where does it go?
- How much water do we need to live, to irrigate plants? How much water do we have?
- What can we do to protect Earth's resources?

Performance Expectations

Students who demonstrate understanding can do the following:

5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: **The geosphere, hydrosphere (including ice), atmosphere, and biosphere are each a system and each system is a part of the whole Earth System (CA)**. Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]

5-ESS2-2. Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth. [*Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere.*]

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet criteria and constraints of the problem.

GRADE FIVE INSTRUCTIONAL SEGMENT 3: INTERACTING EARTH SYSTEMS

3–5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

California clarification statements that are bolded and followed by **CA** *were incorporated by the California Science Expert Review Panel.*

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-2] Developing and Using Models [SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-8] Obtaining, Evaluating, and Communicating Information	ESS2.A: Earth Materials and Systems ESS2.C: The Roles of Water in Earth's Surface Processes ESS3.C: Human Impacts on Earth Systems	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and System Models [CCC-7] Stability and Change

Highlighted California Environmental Principles and Concepts:

Principle I The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

CA CCSS Math Connections: 5.MD.1; 5.MD.5b; 6.RP.3; 5.NF.2; 5.G.2; MP. 2, 6

CA CCSS for ELA/Literacy Connections: SL.5.1, 4, 5

CA ELD Standards Connections: ELD.PI.5.1, 6

To begin, students visit a small ecosystem in their schoolyard. Their goal is to observe and list as many objects in the ecosystem as possible. Returning to the classroom, they look at pictures of more ecosystems (ideally a wide variety of local settings they have visited) and again make lists of all the components in each ecosystem. Students then work in teams to group all these different items into four or five categories. Students will have to formulate these categories themselves based on the similarities they think are most important between groups of objects on their lists. To help students understand the process of making and assigning categories, teachers can demonstrate the process by assigning different items to categories of color (which is not a very useful organizational scheme for scientists). Groups then **communicate [SEP-8]** their rationale for selecting their categories. Professional scientists came up with the categories of Earth's four major systems: geosphere, hydrosphere, atmosphere, and biosphere (table 4.6). These spheres are no more real than the categories students created—they represent a consensus based upon evidence about how objects interact. In fact, some scientists argue that there should be a fifth sphere called the anthrosphere that highlights the importance of humanity and all its creations.

Table 4.6. Earth's Systems

EARTH'S SYSTEMS	EARTH'S MATERIALS
Geosphere	Rocks, minerals, and landforms at Earth's surface and in its interior, including soil, sediment, and molten rocks
Hydrosphere	Water, including ocean water, groundwater, glaciers and ice caps, rivers, lakes, etc.
Atmosphere	Gases surrounding the Earth (i.e., our air)
Biosphere	Living organisms, including humans

Students return to the photographs of the ecosystems and their lists, sorting the objects into the four different Earth systems. All four systems interact (exchange energy and matter) with all the other systems – they are completely interconnected, and as a result significantly influence each other. Students can try to identify some of these interactions in their ecosystem pictures. For example, a river flowing over rocks results in components of the hydrosphere causing erosion in the geosphere and helping support life in the biosphere. The water itself almost certainly comes from clouds in the atmosphere, and the cool water (along with shade from the trees of the biosphere) keeps the temperature low in the atmosphere immediately surrounding riverbanks. Table 4.7 shows a scientist's **model [SEP-2]** for different **cause and effect relationships [CCC 2]** between the different Earth systems. At grade five, students will not have background knowledge of all these interactions, but the blank table itself can prompt them to seek out these relationships. Each of the cells in the table describes one or more specific phenomena that students can investigate. Students should be able to create a **model [SEP-2]** of how one or more phenomena exemplify interactions between different Earth systems (5-ESS2-1). Several processes such as the water cycle (MS-ESS2-4) and the global carbon cycle (HS-ESS2-6) involve complicated interactions between multiple Earth systems and are the focus of middle and high school lessons, respectively. Grade five students focus on simpler interactions between two Earth systems.

Table 4.7. Examples of Interactions Between Earth Systems

		EFFECT			
		GEOSPHERE	HYDROSPHERE	ATMOSPHERE	BIOSPHERE
CAUSE	GEOSPHERE	Rock cycle. Volcanoes erupt lava. Earthquakes thrust up mountains.	Topography affects where rivers go.	Volcanoes erupt gases. Mountains funnel winds and affect the movement of clouds.	Minerals in soil provide nutrients for plants.
	HYDROSPHERE	Water erodes rocks.	Water cycle. Rivers flow into the ocean.	Water evaporates.	Water sustains all life.
	ATMOSPHERE	Chemical weathering of rocks. Wind erodes rocks.	Winds blow clouds.	Weather and climate cycles.	Air sustains all life.
	BIOSPHERE	Decomposers enrich soil.	Plant roots soak up water.	Plants give off water and gases as waste.	Food webs.

Opportunities for ELA/ELD Connections

In small groups, students choose and verbally describe and physically demonstrate the interactions between two of these four systems—geosphere, biosphere, hydrosphere, and atmosphere—using multimedia and/or visual displays. These demonstrations could include students recreating the interaction (e.g., one student is water and another student is wind) to illustrate what happens to land and ecosystems through weather and climate when two systems interact in the atmosphere.

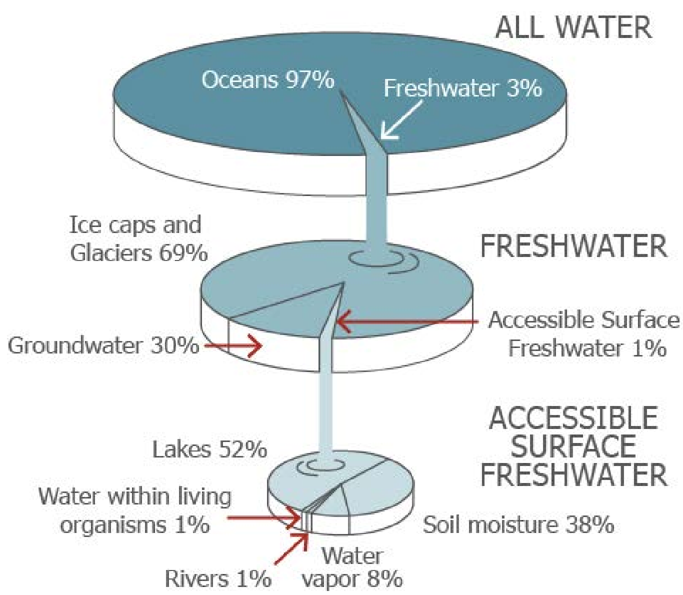
CA CCSS for ELA/Literacy Standards: SL.5.1, 4, 5

CA ELD Standards: ELD.PI.5.1, 6

One of the reasons for describing different Earth systems is to focus on their interactions and how they influence each other, especially the interactions that cross traditional disciplinary boundaries. Just as matter, like contaminants and pollution, crosses these boundaries (EP&C IV), the thinking of citizens of all ages and scientists must do so as well. Examples of contamination in the hydrosphere are tangible, as students already have mental models for how water flows and can extend those models to include interactions with other parts of the Earth system.

As part of their understanding of the hydrosphere, students must be able to describe where water is located on Earth. Students will build on this understanding in grade six when they develop a model of the water cycle (MS-ESS2-4) that describes how water moves within the hydrosphere and into other Earth systems. In addition to knowing where water is located, students should be able to use **mathematical thinking [SEP-5]** to describe the relative proportions of water found in different forms (figure 4.27). How much water is in the ocean, glaciers, rivers, underground? How much is salt water? Students describe and provide evidence that nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere (5-ESS2-2). Humans and all other life depend on this tiny fraction of Earth's water for survival (EP&C I). This relative scarcity is why drought and contamination are such important issues in California, and why human activities can have such large influences on natural cycles (EP&C III).

Figure 4.27. Distribution of Earth's Water



Ninety-seven percent of water is undrinkable (from the oceans) and only 3 percent is fresh water found in icecaps, ground, lakes, rivers and swamps. *Source*: Reiff and Law 2003
Long description of Figure 4.27.

Opportunities for Mathematics Connections

For 5-ESS2-2, students do not study percentages or ratios until grade six. Science teachers will need to provide some background math knowledge on this concept while teaching the science. Students will be able to compare fractions, however. Students could be challenged to find the state, country, or continent with the most/least amount of fresh water per person. Alternatively, students could be assigned a country or continent to investigate. Students could graph their results by liquid or ice form.

CA CCSSM: 6.RP.3, 5.NF.2, 5.G.2, MP. 2, 6

Students can **obtain information [SEP-8]** about the source of their local tap water and which human activities are the primary users of the local water sources. What measures are taken to protect these sources? A field trip to a local wastewater treatment plant or a local farm that uses dry farming techniques can help students think about problems and solutions that help us protect our resources. Student work focuses on **obtaining, evaluating, and communicating information [SEP-8]** that shows how human activities in agriculture, industry, and everyday life have major effects on the land, vegetation, streams, underground water storage levels (aquifer), and ocean (EP&C II).

This focus on water is then broadened to consider other human impacts on all Earth **systems [CCC-4]**. Group projects could investigate particular local resource issues and examine what individuals and communities are doing or could do to help protect Earth's resources and environments (5-ESS3-1). Students present their findings and solutions to each other, emphasizing specific **cause and effect [CCC-2]** relationships where a particular technology or action (EP&C V) prevents the exchange of pollutants between different parts of Earth's systems or otherwise reduces human-induced **changes [CCC-7]** to these systems.

Opportunities for Mathematics Connections

Students create a map of storm water flow on their schoolyard. Where does the water go when it leaves the schoolyard? What contaminants might it pick up and wash into the local waterways? (EP&C II). Using the area they **measure [SEP-5]** on a map of their schoolyard, students calculate the total volume of water that falls on their schoolyard or rooftop in a rainstorm. They **calculate [SEP-5]** how many 55-gallon rain barrels this water would fill up and how long this water would supply their school garden. Students then prepare a presentation to their school site council proposing the installation of a rainwater capture system on their schoolyard such as rain barrels or a cistern.

CA CCSSM: 5.MD.1; 5.MD.5b

Engineering Connection: Design a Simple Water Filtration Process

As water passes through layers of the Earth in nature, contaminants are filtered out or settle. Sometimes, however, humans pollute the water with contaminants that are not naturally filtered out (EP&Cs II, IV). To protect the environment, humans also use water filtration to clean water so that we can use it or it can be returned to the natural environment. In 2014, California's Proposition 1 allocated almost $1.5 billion to groundwater cleanup efforts and future investments are also likely. Engineers will need to develop new techniques and procedures, and existing ones need to be refined to make them more effective and cheaper (EP&C V). In this activity, students play the part of groundwater contaminant engineers and design a simple filter to clean dirty or contaminated water (see "Hands-on Activity: Water Filtration," at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link21). Students **define the problem [SEP-1]**, **gather information [SEP-8]**, **plan a solution [SEP-6]**, and design and carry out a prototype given a set of constraints or limits, such as available materials, money, and/or time. The students can then gather information, work in teams to brainstorm a number of solutions, and compare them against the criteria and constraints of the problem to see which is most likely to succeed. Students are given a sample of "dirty" water made of safe classroom materials like twigs, dirt, sand, brown liquids (tea) and are presented with the challenge of cleaning the water with available materials: cotton balls, coffee filter, etc. Students first design a working **model [SEP-2]**, build it, test it, and then compare their filtered water against a color standard. Students can refine their design by trying to keep it effective but use less material.

IS4

Grade Five Instructional Segment 4: Patterns in the Night Sky

Each night, the Sun appears to set and the stars become visible. At first glance, stars appear to be randomly strewn about the sky with some shining brighter than others. As the human eye is drawn to patterns, ancient people imagined the brightest stars marking the outlines of animals and people. Modern students can use detailed measurements of where stars are in the night sky, how bright they are, and when they become visible to discover patterns in the motion of celestial bodies. IS4 provides the data and analysis that set the stage for much more sophisticated models of planetary motion and the origin of the universe in the middle grades and high school. IS4 has three independent sections: (1) Gravitational Force; (2) Patterns of Motion; and (3) Brightness of Stars.

GRADE FIVE INSTRUCTIONAL SEGMENT 4: PATTERNS IN THE NIGHT SKY

Guiding Questions

- How far away are the stars? How can we tell?
- What trends and patterns are there in the movement of the Sun and stars?

Performance Expectations

Students who demonstrate understanding can do the following:

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down. [Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.] [*Assessment Boundary: Assessment does not include mathematical representation of gravitational force.*]

5-ESS1-2. Represent data in graphical displays to reveal patterns of daily changes in the length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky. [Clarification Statement: Examples of patterns in the sky could include the position and motion of Earth with respect to the Sun and select stars that are visible only in particular months] [*Assessment Boundary: Assessment does not include causes of seasons.*]

5-ESS1-1. Support an argument that differences in the apparent brightness of the Sun compared to other stars is due to their relative distance from Earth. [Clarification Statement: Absolute brightness of stars is the result of a variety of factors. Relative distance from Earth is one factor that affects apparent brightness and is the one selected to be addressed by the performance expectation.] [*Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, and stage).*]

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models	ESS1.A: The Universe and Its Stars ESS1.B: Earth and the Solar System	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation

CA CCSS Math Connections: 4.MD.6; 5.NF.6; 5.G.2

CA CCSS for ELA/Literacy Connections: RI.5.3; W.5.7, 10

CA ELD Standards Connections: ELD.PI.5.1, 5, 11

The night sky is full of wonder. Grade five students should begin by asking questions about the stars, the planets, and space exploration. During this segment, teachers should strive to relate the learning required in the CA NGSS to students' interests and emphasize questions about "how far?" and "how do we know?"

Gravitational Forces Pull Down

Grade five is the first time that students explicitly focus on gravity in the CA NGSS, though they may have used it as an example of a force in grade three. The gravitational force is an extension of other noncontact forces (a force that acts even when objects are not touching) that students investigated in grade three (magnetic and electrostatic electricity). Gravity has a profound impact on our everyday lives and is also foundational to Earth's place in the universe (ESS1), though the connection to planetary motion is beyond grade five. At this point, students just need to gather evidence that gravity always pulls objects downward. Since students cannot directly observe forces, they will need to plan and conduct investigations to help them understand that objects move in the direction in which forces are applied (3-PS2-1). Downward is a relative term—it refers to the center of the planet. For astronauts in orbit, the direction of down is constantly changing as they circle around the planet. They feel weightless because they are constantly falling around the planet.

Opportunities for Mathematics Connections

Students can tie a string to a meter stick and attach a weight to the string. Using a carpenter's level (or calibrated smartphone app), students can arrange the meter stick so that it is perfectly horizontal. Then, students measure the angle between the meter stick and the string. Since gravity always pulls downward, the angle should always be 90 degrees. Students will find it challenging to get precise measurements because the meter stick will not be exactly level and the string will swing back and forth. By sharing multiple measurements, students can see the power of averaging multiple results to minimize experimental error.

CA CCSSM: 4.MD.6

Earth Patterns: From a Day to a Year

Students observed the patterns of shadows, the Sun, and Moon in grade one (1-ESS1-2), but now they bring the more advanced quantitative skills to analyze the data. A fifth-grade class could partner with a first-grade class to collect observations. The fifth graders would prepare graphs and presentations and present them back to their first-grade buddies (planet partners). Students can make graphs of the length of shadows throughout a day, the length of shadows at the same time every day for a month or more, or the number of daylight hours throughout the year. Measurements should begin early in the school year so that students have data to analyze during this instructional segment. Students can use free planetarium software (e.g., Stellarium at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link22) to simulate measurements during the night. Measurements should begin early in the school year so that each student can track a different star every two hours for a week's worth of nights; this can be done much more quickly in a simulator than in real life. After recording data, they can plot their star's position by its compass angle and observe how its position changes. What patterns do they recognize? How often do these patterns repeat? Can they predict the star's position 24 hours in the future? It will be in a similar position, but not identical. How about six months in the future? Some students will discover that their star is not visible six months later. This might prompt students to collect data at longer time intervals such as at the same time every month for a year or two. The goal is for students to recognize that there are multiple cycles of motion occurring simultaneously. The Sun and stars return to a similar location every 24 hours, but their position slowly migrates over the course of 365 days. Students will explain these patterns using a model in the middle grades, but students should recognize similarities between the behavior of the Sun and the stars. These similarities imply that whatever causes one to appear to move likely causes the others.

Opportunities for Mathematics Connections

Students obtain information about sunrise and sunset times from an online database. They calculate the length of daylight by representing hours and minutes as mixed numbers (5.NF.6). They plot the number of hours of daylight versus the number of days since January 1 (numbers from 1–365) in the first quadrant of the coordinate plane. What **trends or patterns [CCC-1]** appear? Students **ask questions [SEP-1]** about what **causes [CCC-2]** these patterns. How long does it take for the pattern to repeat? Having different students use data from different years allows students to recognize that the pattern repeats almost exactly every 365 days.

CA CCSSM: 5.NF.6; 5.G.2

Far, Far Away

Ask students to draw what the night sky looks like and most of them will include a few bright stars surrounded by immense blackness (and possibly the Moon, though it is a feature of the daylight hours as often as it is the night sky). If students observe the night sky through small telescopes or even binoculars, they see that the dark sections of the sky are not as dark as they thought. They are filled with thousands of stars and galaxies too far and too dim to see with the naked eye. Students can experience a similar phenomenon by making a **physical model [SEP-2]** of stars on the schoolyard using flashlights. Each student goes to a different place on the schoolyard and holds an identical flashlight. Students that are close together can see one another's flashlights shining, but it is hard to tell if distant flashlights are on or off. What would happen if one flashlight were brighter than the others? Students can refine their model for what determines the apparent brightness of a star to include both the amount of light energy released by the star (called *absolute brightness* in astronomy) and how far away the star is from Earth.

The Sun is the closest star to Earth and for this reason it appears larger and brighter than any other stars in our galaxy. The factors affecting absolute brightness of stars are beyond the fifth-grade level and students will only be assessed on their understanding of the role of distance in determining apparent brightness (5-ESS1-1). The farthest stars away in the universe are hardly even visible with the best telescopes. When the Hubble space telescope pointed in the same spot in the darkest part of the sky for 10 days straight, it gathered enough to see the faintest stars ever observed. This Hubble Deep Field image (https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link23) is a profound reminder that even something that appears to be nothingness holds more complexity in it than we can imagine.

Science Literacy and English Learners

Science classes are ideal environments for all students to learn and develop language skills. Science and engineering give students something to talk about because they address high-interest topics, manipulate real-world materials, and have collaboration inherent in science and engineering practice. To maximize the synergies between ELD and science, the State Board of Education commissioned a document with examples of how the state ELD standards and the CA NGSS can complement one another (https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link24). Excerpts from that document appear throughout this chapter as “Sample Integration of Science and ELD Standards in the Classroom.”

The vignette below provides a glimpse into a classroom where a deliberate approach to integrate the CA NGSS, CA CCSS for ELA/Literacy, and the CA ELD Standards enhances all three of these areas. Like all the vignettes in this document, this is just one example approach to teaching these standards. In fact, the performance expectations featured in this vignette also appear with snapshots in IS3 in grade three to provide different perspectives on how to teach the same content.

This particular vignette highlights scaffolding approaches for EL students at both the level of lesson organization and individual student interactions. It is not a comprehensive view of all the factors that educators need to consider nor is it universal since pedagogical and scaffolding approaches will depend on individual student needs. Nonetheless, it attempts to illustrate a few research-based instructional practices.

INTEGRATED SCIENCE, ELA, AND ELD IN GRADE SPAN 3–5
VIGNETTE 4.4: BIODIVERSITY IN CHANGING ENVIRONMENTS

Performance Expectations

Students who demonstrate understanding can do the following:

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. [Clarification Statement: Examples of evidence could include needs and characteristics of the organisms and habitats involved. The organisms and their habitat make up a system in which the parts depend on each other.]

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.* [Clarification Statement: Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.] [*Assessment Boundary: Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.*]

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.*

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence	LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS4.C: Adaptation LS4.D: Biodiversity and Humans	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and System Models

Highlighted California Environmental Principles and Concepts:
Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

CA CCSS for ELA/Literacy Connections: W.3.1, 2, 7; SL.3.1, RI.3.3

CA ELD Standards Connections: ELD.PI.3.1, 2, 4, 6, 10, 11, ELD.PII.3.1

INTEGRATED SCIENCE, ELA, AND ELD IN GRADE SPAN 3–5
VIGNETTE 4.4: BIODIVERSITY IN CHANGING ENVIRONMENTS

Introduction

Mr. B's third-grade class is learning how people's activities and behavior can change animal habitats (EP&C II). Mr. B's goal is to provide a variety of rich, hands-on interactive learning experiences in which his students observe the natural world, learn from texts, discuss their thinking, and work collaboratively, all with the goal of making a positive impact on animal habitats through mitigating human damage (EP&C V). Mr. B wants his students both to learn about the area in which they live and understand that they could positively affect the environment through their words and actions. The big ideas that guide Mr. B's planning for the instructional segment are as follows:

- *We can explain why some animals can survive well, some survive less well, and some cannot survive at all in different habitats.*
- *We can explain how humans impact animal habitats and make an argument for protecting them by making evidence-based claims.*

Mr. B's class of 34 students is comprised of 20 native English speakers or students who are bilingual and proficient in English and 14 students who are ELs. Of the 20 students proficient in English, the majority speak a nonstandard variety of English or a language other than English with their families. Twelve of the ELs are at the Expanding or early Bridging level of English proficiency and use everyday English comfortably. Two of Mr. B's students have recently arrived in the United States and are at the early Emerging level of English proficiency. The majority of Mr. B's ELs and many of his bilingual students speak Spanish as their home language, but he has two students who speak Hmong as a home language. Mr. B's goal is for each of his students to successfully engage in the academic and linguistic content of the class, and he works hard to provide the supports necessary for them to succeed.

Lesson Context

Investigative phenomenon: Different numbers and types of plants and animals grow in different parts of the schoolyard.

Earlier in the year in a previous instructional segment, students began to learn what plants need in order to grow and what they get from the ecosystems where they live. In this instructional segment, Mr. B's students have started to learn about the diversity of life in different habitats. He started the learning segment by taking his students on a field trip in which they spent the morning examining nearby habitats. To help his students become excellent observers and data collectors, he asked them to take their science notebooks with them to make notes, in whichever language they were most comfortable writing, and to draw pictures about the plant and animal life they observed. The students examined the school garden, the neighborhood near the school, and a nearby wooded park. Students recorded the number of different plants and animals in each area. When they returned to the classroom, the students discussed the differences in the living things they observed in each habitat, and Mr. B led the class through

INTEGRATED SCIENCE, ELA, AND ELD IN GRADE SPAN 3–5
VIGNETTE 4.4: BIODIVERSITY IN CHANGING ENVIRONMENTS

a discussion that culminated in the jointly constructed statement: "Different numbers and types of living things, including plants and animals, live in different habitats." Mr. B facilitated a class conversation about what data could be used to support this statement such as the number of different trees observed in each area. This is added to the statement.

Investigative phenomenon: Different plants and animals grow in different parts of California.

Mr. B and his students had also read and collaboratively discussed two informational texts, "Would Blackberries Grow…?" and "What a Joshua Tree Needs from the Desert" (available at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link25). Mr. B posted Word Wall Cards (available at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link26), and he helped the students add translations of the words in their home languages. Mr. B taught these words to students, and he modeled how to use them as often as he could. Additionally, Mr. B facilitated a discussion in which his students connected their observations of the diversity of life in the habitats they observed and read about to the California Habitats wall map (available at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link27). The students wrote sentences that described the similarities and differences between what they observed on their nature walk and the plants and animals highlighted on the map.

The children were building both their science conceptual understandings and language and literacy skills, all of which they used to create informational posters that included an evidence-based argument about how some animals survive well, less well, or not at all in a particular habitat; photographs or illustrations that show the animal habitats they have researched; data that show human impact on the habitat (graphs or tables); and suggestions for what students and their families can do to reduce the impact humans make on animal habitats. The students presented their posters to their families on the school's Family Science Exhibition Night. Each student also wrote a letter to the editor of the local newspaper to engage the community to care about and protect local animal habitats. The following learning target and CA NGSS performance expectations guide teaching and learning for the lesson.

Learning Target

We will create posters that explain how humans affect animal habitats and suggest ways we can protect them (EP&Cs II, V). We will write letters to the editor arguing why we should protect animal habitats.

CA NGSS Performance Expectations

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

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Lesson Excerpts

Since Mr. B's students had started to build up an understanding of animal and plant diversity in habitats, he was ready for them to begin examining the impact humans have on animal habitats. He posted two questions that the children would consider over the course of the next several days:

- How can human activities change the habitats where plants and animals live?
- How do these changes affect the survival of the plants and animals that live there?

Everyday phenomenon: Animals lose their homes when people cut down trees.

Mr. B began the lesson by asking the class to think about a human activity that might affect an animal's habitat. He first gave an example: When humans cut trees down to make things, like houses and paper, some animals might lose their homes. Then, he asked his students to think about as many ideas as they could and gave them a few moments to do so. As the students thought, Mr. B checked in with his two students at the Emerging level of English language proficiency to ensure they understand the question. After the students had had time to think, Mr. B asked them to share with their partners using an open sentence frame in order to challenge them to include human impact and its effects:

When humans _________________ (cause), ___________ (effect), **[CCC-2]**.

He listened in as students shared their ideas. He heard some students share an idea very similar to his, while other students said things such as, "When humans make a parking lot, and that's where there were trees before, I think it causes animals to lose their homes, like birds and squirrels and stuff," and "When humans put pollution in the air, because they're driving their cars a lot, I think the animals can get sick or die because they can't breathe clean air."

Meaningful Interaction with Science Informational Texts:

Mr. B's next step was to help his class to understand deeply the relationship between an animal, the animal's habitat, and human actions that affect an animal's habitat. To help build his students' understanding, he chose the relationship between the monarch butterfly, the milkweed plant, and the elimination of milkweed due to human use of weed killer (EP&C II).

Investigative phenomenon: Mallow plants grow taller when they have the right amount of water and sunlight.

To provide context to the monarch story, Mr. B had his students raise painted lady caterpillars and mallow plants in the classroom. Students planned and conducted investigations about how the amount of water and sunlight might affect the height of the mallow plants (3-LS3-2).

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Investigative phenomenon: Caterpillars follow a specific life cycle and grow into butterflies.

Students also observed the development of the caterpillars into a chrysalis and then an adult butterfly. Students conducted safe and respectful investigations to understand how the environment (food, water, space) could affect the butterfly. These investigations were necessary to provide context when students interacted with informational text. The data from the investigation would also be used when students needed evidence to support their claims later in the unit.

Investigative phenomenon: Monarch caterpillars eat milkweed plants.

Mr. B read aloud the informational text *Monarch and Milkweed* by Helen Frost and Leonid Gore. He read the text to the children as they sat on the carpet. Being cognizant of each student's level of English proficiency as well as science content knowledge, Mr. B pre-assigned students to heterogeneous partnerships so all student had thinking buddies. Mr. B reminded students that they had already learned a great deal about another type of butterfly, the painted lady, as well as one of the butterfly's food sources, the mallow plant. He explained that they were now going to learn about another butterfly, the monarch. As Mr. B read, he stopped periodically to define words and to prompt his students to repeat words and definitions and to make an accompanying hand gesture that will help them remember the words. For example, when Mr. B came to the word *migrate*, he said, "Migrate means to travel in a group from one place to another." He said the word clearly and then asked his students to chorally repeat the word and the definition while also making the motion of moving their hands from the center of their chest straight out away from themselves, making wriggle fingers to show both movement and that it is a group of many.

Throughout the book, Mr. B stopped periodically to ask students questions and make connections to their previous butterfly investigations. He also allowed them time to think then share with their partners after each question, to ensure they understood the reading. He emphasized how illustrations can help the students understand the scientific concepts, as when an illustration shows the caterpillar inside the chrysalis. He asked students to compare the illustrations in the text with their own drawings of the painted lady butterflies from their previous investigations.

When Mr. B got to the end of the book, he asked his students to discuss with their partners the questions: What would happen if most of the milkweed were gone? What did we learn about the painted lady butterfly and the mallow plant? He listened closely as partners discussed. Once the students had had about a minute to discuss with their partners, he brought the class back together and asked a few partners to share out. Mr. B had an instructional routine in which

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when one partner shares, and the other partner also has to share by adding on to their partner's response.

Mr. B called on a pair of students, Veronica, who is at the early Emerging level of English language proficiency and has a grasp of some academic Spanish because of her schooling in Mexico, and her thinking buddy, Alicia, who is bilingual. Both girls speak Spanish as their home language.

Mr. B: Veronica and Alicia, I would like you to respond. Which of you will go first? (Veronica and Alicia confer briefly.)

Alicia: I'll go first and Veronica will add on. We think the butterflies will die.

Mr. B: Yes, that does seem likely. I'd like to hear more. Why do you think the butterflies will die? Veronica, can you say more?

Veronica: I…I think…

Alicia: (whispering to Veronica to prompt her) I would like to add…

Veronica: I would like to add…that…butterflies need milkweed to…*¿Cómo se dice sobrevivir?*

Alicia: *¿Sobrevivir?* Uh … Survive!

Veronica: Butterflies need milkweed to survive, so…*cuando*…when the milkweed… (turning to Alicia) *¿Puedes decirlo tu?*

Alicia: If all the milkweed is gone, the butterflies would die.

Mr. B: Thank you, Veronica and Alicia. (He writes under the document camera, "Butterflies need milkweed to survive, so when the milkweed is gone the butterflies die.") (To Veronica and Alicia) Is that right? (Both girls nod their heads). Let's see if we can expand on that idea a little bit. (Mr. B chooses another pair to share, Bryan and Santiago. Bryan is a native English speaker and Santiago is an English Learner at the early Bridging level of English proficiency). Bryan and Santiago, can you elaborate on Veronica and Alicia's ideas?

Bryan: The butterflies are a special kind called monarch butterflies.

Mr. B: (Adds the word monarch before butterflies in Alicia and Veronica's sentence.) Thank you for being specific about the type of butterfly.

Santiago: I don't know what else to say.

Mr. B: Let's see if we can figure it out together. Can you say anything more about this idea of the butterfly surviving? Can we unpack that a little bit? (Picking up on the students' hesitation, Mr. B makes an adjustment to address vocabulary.) In fact, this might be a new word for some of us. Let's all say the word survive. (The class chorally says the word.) Survive means to continue to live. Let's all say that. Survive means to continue to live. (The class chorally repeats the definition.)

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Mr. B quickly provided the sentence frame: "_____ helps ______ survive by …" He said, "We're going to practice using the word survive." He modeled, touching the appropriate part of the posted frame as he spoke, "Sunlight helps plants survive by providing energy for plants to turn into food." He had students take turns completing the sentence frame with their elbow partners for one minute. During this time, Mr. B paid particular attention to the sentences the ELs produce; he used these observations when determining what kind of support to provide during subsequent tasks. Mr. B then gave students another 30 seconds to practice completing the sentence frame, this time focusing their sentences only on monarch butterflies.

Mr. B: Santiago, what is one way milkweed helps the monarch butterfly survive? I'd like you to use the stem "Milkweed helps the monarch butterfly survive by…" (Mr. B writes this stem below the document camera, under the sentence the class has started.)

Santiago: Umm. Okay. Milkweed helps the monarch survive by giving it… Can you go back to the page about the caterpillar?

Mr. B: (Opens the book to the page about the caterpillar.) This one?

Santiago: Yeah. Milkweed helps the monarch butterfly survive because… it hangs on the leaf.

Mr. B: The caterpillar is hanging there, yes. Let's brainstorm a list of all the ways the milkweed plant helps the monarch butterfly.

He writes, The milkweed plant helps the monarch butterfly by providing a place for the caterpillar to hang while it grows. He prompts the class to echo read the statement; this practice gives all students an opportunity to develop their expressive reading skills. Mr. B continues to elicit responses from different students, supporting them as they develop their ideas and clarify their understandings about the importance of the milkweed plant to the life cycle of the monarch.

Investigative phenomenon: Monarch butterfly populations are shrinking.

The next day, Mr. B had the class engage in an "Expert Group Jigsaw" reading using texts about threats to the monarch butterfly (including a Newsela article called "Scientists worry over disappearing monarch butterfly"). The children had engaged in this type of collaborative reading activity before and enjoy its game-like flavor. They took their science notebooks, which they used to take notes, as they convened in their expert groups. The process they used was as follows:

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Expert Group Jigsaw Procedure

Step 1: Students read a text independently in their Expert Groups. The expert groups convened. Sometimes, groups would be put together randomly (by counting off, for example). At other times, teachers wanted to group students strategically to balance/leverage strengths, learning needs, and interests. Each person in the same expert group read the same text, but each of the different expert groups read a different text. This could be different sections from the same text, or it could be different texts that provide various lenses on the same topic. Each student read their text independently, along with focus questions and a note-taking guide (graphic organizer) to take notes.

Step 2: Students become experts in their Expert Groups. In this step, each person was responsible for adding information from their independent reading, noting (in their note-taking guide) what others shared, and building on what has been shared. After the initial sharing, the students moved on to discussion questions about the text where they could delve deeper into the text together and further develop their expertise of the topic. At the end of this phase, the group members agreed on key points they would each share in their jigsaw groups.

Step 3: Students share their expertise and learn from others in Jigsaw Groups. Students convened in their jigsaw groups, comprised of one (or two) people from each expert group. Each person shared their expertise while the others took notes and asked clarification or elaboration questions. Once each person had shared, the group sometimes had an additional task, such as synthesizing the information that had been shared or discussing one or more of the big ideas from the different readings.

Step 4: Students share what they learned in their Expert Groups.

After the class had researched the threats facing the monarch butterfly, Mr. B asked students the two overarching questions for the instructional segment:

- How can human activities change the habitats where plants and animals live?
- How do these changes affect the survival of the plants and animals that live there?

The children discussed these questions in small groups of four students, who then have an opportunity to share out their responses.

Preparing to Create Posters

After his students had connected closely with the idea that humans can impact the habitats of animals (EP&C II), Mr. B wanted to bring their understanding back to the animal habitats around the school.

Mr. B took the class on a second nature walk. The students explored an unused parking lot near the school, and they made a return visit to the nearby wooded park. As they visited these sites, the students made notes and/or simple drawings in their science notebooks about the condition of the habitats and abundance of plants and animals in each. They also made observations about the number of different plants and animals in each area. Mr. B told his students to note if an area had lots of different plants and animals, if it had mostly one type covering the area, or if there were few plants and animals over all. He encouraged his students to record specific data such as numbers of plant types or descriptive words from their word bank.

Once the class returned to the classroom, Mr. B led a Talking Points activity to help his

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students bolster their learning and understanding. In this activity, Mr. B wrote a series of statements related to the lesson's learning goals, and students had to agree or disagree with the statement, using evidence to support their stance.

Mr. B wrote the statements on a piece of paper and using the document camera, revealed one at a time. Both to prompt all students to include their rationale and/or evidence in their responses and to support ELs who may need help structuring their responses, Mr. B included sentence frames:

- Some habitats have more plants and animals than others. (I agree/disagree that some habitats have more plants and animals than others because ____________.)
- An animal's habitat helps it to survive, or live. (I agree/disagree that an animal's habitat helps it to survive because ____________.)
- Humans have no impact on animal habitats. (I agree/disagree that humans have no impact on animal habitats because ____________.)
- Humans can help make animal habitats healthier. (I agree/disagree that humans can help make animal habitats healthier because ____________.)

After he uncovered each statement, Mr. B asked the students to turn and talk with their thinking buddies. He encouraged students to use data from their nature walk to support their statements. Mr. B made a point to listen to all of his students' conversations, but he took special care to ensure his EL students had understood the task and were actively participating.

As students shared out, Mr. B charted their ideas because he wanted students to be able to use these ideas when they made their posters. He didn't write the exact words the students said. Instead, he worked with students to jointly construct statements, making sure to capture students' intended meaning in error-free, grammatically sound sentences. He created an anchor chart for each statement that included different pieces of evidence students gave to support their ideas. Two sample anchor charts for the statements are shown below.

Statement: Some habitats have more plants and animals than others.

We agree!

- We observed many different types of plants and animals in the park. There were at least five different types of trees and we counted six squirrels and four kinds of different birds.
- We observed almost no plants or animals in the parking lot. Some weeds grew through cracks. Only one bird was standing on the edge of the parking lot.

Statement: Humans have no impact on habitats.

We disagree!

- People paved the parking lot so no trees are left there. Without trees, many animals have no home.
- People killed milkweed with weed killer. Monarchs need milkweed to survive. Milkweed is important to the monarch habitat.
- People build whole cities and the animals have to find somewhere else to live.

After Mr. B had worked with his students to create each of the three anchor charts, he challenged them to come up with ideas about what they as individuals or as a class might do

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to decrease the effects of human activities on the habitats of plants and animals (EP&C V). Mr. B's class came up with many great ideas, such as the following: plant milkweed in the school garden; use less paper so we have to cut down fewer trees; and pick up trash from the park. Mr. B charted these ideas as well, leaving them up as support for students when they create their own lists of suggestions for their posters. Mr. B encouraged his students to justify the merit of their solution with evidence from their investigations.

Mr. B concluded that students were prepared to move into writing. He wanted to support his students in successfully writing an informational report, so he brought out a model text that he had created. Mr. B wanted to help his students learn about the features of the type of text they would write, but he wanted students to use their own ideas for the text they would write independently. So the model text was written in the style of an informational report, but on a subject the class studied earlier in the year— what plants and animals need to survive. The class examined the purpose of the text (to provide information), as well as the parts of the text, including the claim (general topic statement), followed by several pieces of data from investigations and details that support the claim, and then a concluding statement.

Before releasing students to write on their own, Mr. B led his students through jointly constructing a text on a closely related topic: How does its habitat help an animal survive? The students were sitting on the carpet next to their thinking buddy while Mr. B wrote the text on chart paper. The class decided to focus its informational report on one animal with which the students were all familiar—the monarch butterfly. Mr. B helped his students refine their thinking and phrasing, as necessary, as they worked to jointly construct an informational report.

Mr. B: We first have to tell our reader what we're going to be writing about. What could we say? (He gives students about 10 seconds to think.)

Npaim: We could say we're going to tell you all about monarch butterflies!

Mr. B: That's certainly accurate! I wonder if there's a way that we can tell our readers a little bit more.

Npaim: Oh! Their habitats. We're going to tell you all about the habitat of the monarch butterfly.

José Luis: Yes, they have to have...what's it called? That milk plant?

Adriana: Umm...milkweed!

Mr. B: Thank you for sharing your ideas! Let's see if we can turn that into a sentence that makes us sound like scientists. What if we write, "The monarch butterfly depends on—that's another way to say *has to have*—milkweed to survive?"

Npaim: But, we didn't use habitats.

Mr. B: Thank you for that observation. Let's make sure we use the word habitat. Does anyone have any ideas on how to use the word habitat here?

Mr. B continued to facilitate the discussion as he and the class jointly construct the text, paying careful attention to the structure, thus "apprenticing" his students into using the language of science.

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Mr. B continued to facilitate the discussion as he and the class jointly construct the text, paying careful attention to the structure, thus "apprenticing" his students into using the language of science. Once they had jointly constructed the text, Mr. B released most of the class to independently write the informational report that would go on their posters. He directed the students to the anchor charts on the walls as well as the Word Wall. His students also knew that they could rely on one another as resources when they were writing. While most of the class was writing independently, Mr. B pulled a small group—his students at the early Emerging level of English language proficiency and two other students whom he has determined need additional, individualized support with their writing. With these students, he provided greater scaffolding throughout the writing process, first by helping them brainstorm and outline their ideas and then with more one-on-one support as they constructed their informational reports.

Once students had finished their informational reports, Mr. B led the class through a peer review, in which each student compared their informational report with that of another student. Mr. B told the students that they should compare how evidence from the investigations was used in the text. Was it convincing? Was there enough evidence? Did the evidence fit with the claim (appropriate)? He also asked students to compare the logic used to connect the evidence to the claim. Was it convincing? Mr. B provided a checklist of the features each report should include to assist students as they worked together, and he rotated around the room as students shared and discussed their writing, providing assistance as needed. He then delivered a mini-lesson on expanding their writing by including additional evidence, after which each student expanded at least one sentence in their informational reports.

Once students had finished revising their informational reports, they finished their posters by writing a list of ways humans can help restore or protect animal habitats (EP&C V). They also found pictures and drew illustrations that showed the animals and habitats they wrote about. The students presented their posters to their parents at the school's Family Science Exhibition Night. They led their families on a gallery walk of the classroom, serving as docents, as they explained the posters and helped them conduct some science investigations at the many stations around the room.

Collaborative Research Projects and Engaging the Local Community

Investigative phenomenon: How can humans reduce their impact on local wildlife?

After researching and creating posters about the monarch butterfly and its habitat, the class delved into collaborative research projects in small groups (three to five children in each group). Mr. B invited several speakers to share their knowledge with the class, including a wildlife biologist from the local university and a docent from a local wildlife conservation center. After hearing and reading about different animal habitats that are under threat from human impact, in their small research groups, the children selected a California animal habitat under threat, researched it together, and individually wrote letters to the editor of the local newspaper to inform the public and engage them in thinking about environmental protection.

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To learn how to write effective letters to the editor (arguments), Mr. B supported the students as they analyzed published letters written by other students in grades three through five, such as the following:

Balance wildlife and energy needs

Wind power is both a valuable source of renewable energy and a terrible threat to birds and bats. Wind turbines—located in the Altamont Pass, Tehachapi Mountains and the Montezuma Hills—kill birds in flight and they take up valuable habitat.

Wind turbines kill roughly 108,000 birds and thousands of bats each year in California. A recent study published in Biological Conservation says that while 10 percent of the United States' wind energy is produced in California, 46 percent of all yearly wildlife kills are caused by California's wind turbines.

Although there are other causes of bird deaths— like collisions with telephone wires and buildings and attacks by house cats and feral cats —turbines are an important problem, especially for raptors, which glide with the wind and are often found in windy places where the turbines are located.

California Department of Fish and Wildlife biologist Elliot Chasin says one solution is to locate wind farms in altered lands far from nesting habitats. Using shrouded turbines also helps birds avoid the blades. You can help by telling your elected officials that it is important to balance the needs of wildlife with the needs for renewable energy.

Braeden Ingram
Fifth grader
Korematsu Elementary School

Pesticides can do great harm

My name is Emily Jiang and I am part of my school Nature Bowl team. I am currently working on an environmercial. That is an environmental report on a local issue. My issue is biomagnification and bioaccumulation of legacy pesticides.

Just to be clear, biomagnification is the increasing concentration toxins as they moves up a food chain. Bioaccumulation is the increasing concentration of a toxin from the environment to the first organism in a food chain. Legacy pesticides are a group of banned pesticides that include dichlorodiphenyltrichloroethane (DDT), the chlordanes and dieldrin. So if you put them together, it equals an amazing but deadly link.

Here's an example: If a sufficient amount of DDT was sprayed on a marsh to control mosquitos, then plankton will eat that, and then a clam will eat that plankton, and then a gull will eat that clam.

But then the amount of DDT in that gull will be lethal, killing that bird.

You see how big of a problem this is. But many people don't. They think that when they spray a pesticide onto some grass, or on a marsh, at most it will harm a small insect. That can cause a huge blowout, which will end up harming a much larger and threatened organism.

There are plenty of ways I am going to help. The best way will be to raise awareness. But what you can do is to tell your friends how big of a problem this is, and have them tell their friends. Hopefully, this will make people think twice about using dangerous pesticides like the legacy pesticides.

Thank you very much for taking part in helping our society.

Emily Jiang
Davis

(Ingram 2014, Jiang 2014)

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Some of the letters to the editor called for people to spread the word or call their local representatives. Others provided suggestions for taking action in daily life. Mr. B and the parent volunteers took care to avoid influencing the position that students were taking, limiting their guidance to supporting the development of students' writing skills. Students, working in small groups, completed appropriate editing and revision; then they had writing conferences with Mr. B and parent volunteers (over the course of the next several months), each of the children's letters was published in the local newspaper and/or an online venue. In addition, the children were inspired by some of the letters they read to produce their own short *environmercials*, which the principal of their school posted to the school Web site.

Teacher Reflection and Next Steps

During all of the conversations and tasks, Mr. B had been observing his students carefully so that he could plan appropriately for their learning for the rest of the instructional segment. He saw that some of his students were having trouble using sufficient details in their writing, while others were veering from the topic. This prompted him to incorporate more tasks into future lessons to help his students use more details and stick more closely to the topic they were writing about. He knows from analyzing student writing and monitoring their conversations that most students understood the big ideas of the lesson, so he planned to design and implement more well-rounded lessons in which students have multiple opportunities to interact with one another as they work with science concepts in a real-world context.

During designated ELD time, Mr. B also used his observations, notes, and the CA ELD Standards to plan focused language development lessons that built into or extended from his integrated lessons. He had noticed that the EL students at the Emerging level of ELD were using more everyday and social language but needed more support with academic vocabulary. He planned several vocabulary lessons for designated ELD time so that students had a range of opportunities to use the target general academic (Tier 2) and domain-specific (Tier 3) words, as well as lessons that look specifically at language features used within informational reports (e.g., subheadings to organize information, present tense, etc.).

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