INTRODUCTION

Scientists and engineers investigate science phenomena in specific ways, referred to in *A Framework for K–12 Science Education* and the *Next Generation Science Standards* as science and engineering practices. In the classroom, these practices are often visible as students conduct investigations, obtain information, and develop scientific models. Less visible are the cognitive processes students use to connect science knowledge to the world around them. What cognitive tools are they using to think about phenomena? What lenses do they look through? These often invisible, analytical connective frameworks are called crosscutting concepts.

*These concepts help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world.*

Although crosscutting concepts are fundamental to an understanding of science and engineering, students have often been expected to build such knowledge without any explicit instructional support. … Explicit reference to the concepts, as well as their emergence in multiple disciplinary contexts, can help students develop a cumulative, coherent, and usable understanding of science and engineering (*A Framework for K–12 Science Education*, 2012, page 83).
Crosscutting Concepts

Crosscutting concepts serve as a bridge—spanning life, earth and space, and physical sciences and connecting the disciplinary core ideas of science. They are a common thread from the beginning of the school year to the end. Most importantly, they serve as a bridge between knowledge and experience, one that provides access to a deeper understanding of the world around us.

These are the seven crosscutting concepts as they appear in *A Framework for K–12 Science Education* (page 84). They are stated in general terms and not specific to grade 4 capabilities as will be done later in this chapter for each concept.

1. **Patterns.** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

2. **Cause and effect: Mechanism and explanation.** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. **Scale, proportion, and quantity.** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.

4. **Systems and system models.** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

5. **Energy and matter: Flows, cycles, and conservation.** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.

6. **Structure and function.** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. **Stability and change.** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.
Next Generation Science Standards (appendix G) identifies several guiding principles for using crosscutting concepts with students.

• Crosscutting concepts can help students better understand core ideas in science and engineering.
• Crosscutting concepts can help students better understand science and engineering practices.
• Repetition in different contexts will be necessary to build familiarity.
• Crosscutting concepts should grow in complexity and sophistication across the grades.
• Crosscutting concepts can provide a common vocabulary for science and engineering.
• Crosscutting concepts should not be assessed separately from practices or core ideas.
• Performance expectations focus on some but not all capabilities associated with a crosscutting concept.
• Crosscutting concepts are for all students.

These guiding principles demonstrate that crosscutting concepts are a vital part of classroom instruction.
Crosscutting Concepts in FOSS Investigations

Crosscutting concepts should be explicitly taught to students. They need to exercise them with guidance and feedback. Initially, students at the elementary level will not know when or how to think about crosscutting concepts. You will need to identify which crosscutting concepts are most helpful for students and to plan instructional strategies and questions that will support and guide students. Most lessons, whether they are one session or several, incorporate a crosscutting concept. Students can often use crosscutting concepts during a sense-making discussion as a lens to process and think more deeply about their experiences and the science ideas they are working on.

In the FOSS Investigation Guide, opportunities to introduce and exercise crosscutting concepts appear in a green call-out in the sidebar next to the steps that implement them. The table “Crosscutting Concepts Opportunities in FOSS” at the end of this chapter is the complete list.

The following pages describe crosscutting concepts and fourth-grade student capabilities when using them. These capabilities suggest how to introduce a crosscutting concept, and strategies and questions that can be used in sense-making discussions.

For grade 4, we recommend focusing on the crosscutting concepts of patterns, cause and effect, systems and system models, and energy and matter, as those provide a sound foundation for students, and are also incorporated into the NGSS Performance Expectations at this grade level. The remaining crosscutting concepts can and should be exercised in fourth grade as well, but they are emphasized in other grade levels.

In the Wrap-Up for each investigation, the review of the phenomena through the focus and guiding questions should also involve discussion about the crosscutting concepts that were useful in thinking about the phenomena. In the Wrap-Up section of the FOSS Investigations Guide, developers have summarized the core ideas that students experience in the investigation and the relevant crosscutting concepts associated with each idea. In later grades, students will generate those crosscutting concepts as part of the review.
The FOSS developers have selected a few of these crosscutting concept opportunities in investigations in each module and given them special emphasis in the Investigations Guide with a green call-out plus a crosscutting-concept icon and a narrative note (as shown in the sidebar). These Grade-level Examples, shown in the table below for grade four and discussed in this chapter, can bridge between FOSS modules (instructional segments).

The crosscutting-concept dimension of the NGSS will take time to integrate into your practice. Students have had several years working with these concepts and will continue to progress incrementally. They will start learning the crosscutting concepts with explicit support. Then they will use their knowledge of crosscutting concepts as tools to think about the disciplinary core ideas they are working on. They will use the crosscutting concepts to understand the connections and interactions between the disciplinary core ideas. In the end, they will be able to make sense of their environment and natural systems, using their knowledge of the crosscutting concepts lens for intellectual integration. But it won’t happen in a lesson or a year; it will grow and develop over years as students engage more deeply with their science studies.

### Grade-level Examples for Crosscutting Concepts Described in This Chapter

<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
<th>Soils, Rocks, and Landforms Module</th>
<th>Energy Module</th>
<th>Environments Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns</td>
<td></td>
<td></td>
<td>Inv 4, Part 2, Step 11: Look for plant patterns</td>
</tr>
<tr>
<td>Cause and effect</td>
<td>Inv 1, Part 2, Step 15: Share notebook entries</td>
<td>Inv 1, Part 3, Step 30: Have a sense-making discussion</td>
<td>Inv 5, Part 3, Step 7: Have a sense-making discussion</td>
</tr>
<tr>
<td>Scale, proportion, and quantity</td>
<td>Inv 3, Part 2, Step 7: Compare profiles and mountains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems and system models</td>
<td></td>
<td></td>
<td>Inv 2, Part 1, Step 17: Introduce ecosystem</td>
</tr>
<tr>
<td>Energy and matter</td>
<td>Inv 3, Part 3, Step 19: Troubleshoot problems</td>
<td>Inv 4, Part 3, Step 13: Analyze the results in terms of energy</td>
<td>Inv 2, Part 2, Step 7: Introduce producer</td>
</tr>
<tr>
<td>Structure and function</td>
<td></td>
<td></td>
<td>Inv 1, Part 3, Step 19: Use a concept grid</td>
</tr>
<tr>
<td>Stability and change</td>
<td>Inv 3, Part 4, Step 5: Discuss rapid changes</td>
<td></td>
<td>Inv 2, Part 2, Step 26: Discuss basic need for oxygen</td>
</tr>
</tbody>
</table>

Go to FOSSweb for Teacher Resources and look for the Crosscutting Concepts—Grade 4 chapter for details on how to engage students with the concept of cause and effect.
WORKING CROSSCUTTING CONCEPTS INTO INSTRUCTION

**Patterns**

Recognizing patterns starts at a very early age, even before children can formulate words to describe them. Children test and retest those patterns to verify their observations—rolling balls, pressing buttons to activate electronic devices, and playing peek-a-boo. They are curious, and sometimes upset, when patterns change. These experiences lay the groundwork for scientific study as children enter school and are introduced to patterns in the natural world.

*Patterns exist everywhere—in regularly occurring shapes or structures and in repeating events and relationships…. Noticing patterns is often a first step to organizing and asking scientific questions about why and how the patterns occur.*

One major use of pattern recognition is in classification, which depends on careful observation of similarities and differences (A Framework for K–12 Science Education, 2012, page 85).

**Capabilities of students.** In grades 3–5, students identify similarities and differences in order to sort and classify natural objects and designed products. They identify patterns related to time (sequences), including simple rates of change and cycles, and use these patterns to make predictions (Next Generation Science Standards, Appendix G, 2013, page 82).

**Introducing patterns.** When introducing the crosscutting concept of patterns, have students work with materials and carefully make observations firsthand. When students have had ample time to explore the pattern, whether it is a mathematical pattern or observation of properties of objects, gather students for a discussion.

Ask a guiding question so students focus on the target concept, pattern. This may require some probing questions, such as

➤ *Was there something that was the same for all the objects? Is that pattern always true?*

For mathematical patterns, the data should be organized and displayed in tables or graphs so that students can recognize the pattern. These questions can guide students to understand the meaning of *pattern*, as well as to recognize the pattern in the data.

➤ *When we look at these results, what do you see? Is there a pattern in the way the numbers increase or decrease?*

Once students have reported their observations and described the pattern, define and reinforce the word *pattern.*
Patterns in science help scientists study the world around them. Scientists look for things that repeat, increase, or decrease. They look for things or characteristics that are different or the same about what they are studying. <Repeat the pattern students reported.> This is a pattern that you observed.

If you have explored mathematical patterns, point out the connection to those and ask students to identify the patterns.

In math, what patterns have we observed? In science, when we make observations, we always look for patterns. We can ask questions about patterns. We can test those questions. We can try to figure out why those patterns happen, and we can use patterns to help explain the phenomena we are studying.

**General strategies for patterns.**

- Start with focusing students on two objects, such as two vials containing soil (data points). Ask them to compare the two. Add a third. What is the same or different with all three of these? If students determine the objects all have a particular property or characteristic, provide a nonexample and ask students if it is an example.
- Use a graph to identify to explore a pattern. (See the example from the Energy Module in the sidebar.)
- Once students are able to determine a pattern, ask students to develop a ‘rule’ about the pattern of the objects (or data points). A statement of a rule is akin to a claim. Provide additional examples and nonexamples for students to sort into ones that fit the pattern and ones that do not.

**Sentence frames for patterns.**

- I notice that _______ is the same for these objects.
- I notice that _______ is different for these objects.
- I wonder if _______ fits the pattern.
- I can test this pattern by _______.
- This pattern is similar to _______.

**Taking it further.**

- Ask students to share different ways they can represent patterns in their science notebooks.
• Create an ongoing lists of patterns. Have students generate the headers for these lists, such as, *Natural* (all soils have ...) or *Tested* (objects rolled from a higher height go faster than those rolled at a lower height.)

• Discuss why scientists and engineers look for patterns. Ask students how patterns help them understand more about the system or phenomenon.

**Grade-level examples.** In the *Environments Module*, Investigation 4, Part 2, students look in the schoolyard and map plant species using a plant-identification key. Have students look at the distribution of plants, indicated by colored Xs on their map, in the schoolyard. Ask questions, such as, “Do you see any of the colors in a certain area?” If students notice certain plants are located next to a building, ask, “What are the conditions like in that area? What does that tell us about why those plants are there?” Plants growing in a particular area and not others is a pattern. After identifying whether the pattern is natural or human influenced (shade trees planted in a row), ask students if a particular plant would be likely to grow in a different area. For example, if students notice a plant grows only in open areas with lots of sunshine, ask them if it would be likely to find the plant in the wooden area in the park. Show students other types of areas and ask them to make predictions based on their patterns. As more and more observations are made and analyzed, students refine the plant patterns.

**Connections between modules.** In this section, some of the connections between modules are shared. The purpose of sharing these connections is for teachers to bridge investigations and modules using a particular crosscutting concept. Once students have started using one crosscutting concept, such as patterns, in one context, connections can be made to that experience the next time students experience patterns. Fourth-grade students have used patterns and other crosscutting concepts for several years. Draw on their previous experiences, while the context changes, these thinking strategies are universal. As students’ use of patterns increases, they will identify opportunities to look for patterns or even look for them without being asked to do so.

In the *Soils, Rocks, and Landforms Module*, students observe erosion and deposition. Students determine patterns such as water flows downhill, bigger (heavier) pieces of earth material settle first while lighter material is carried farther by water. In the *Energy Module*, students describe the pattern of waves. While challenging, even for older students, waves have patterns. Students can compare the patterns of the waves to determine similarities in frequency, amplitude, and wavelength.

**CROSSCUTTING CONCEPTS**

**Patterns**

**NOTE**

In the *Investigations Guide*, you are directed to this Crosscutting Concepts—Grade 4 chapter for information on how to engage students with the concept of patterns.

**NOTE**

Additional connections between modules are displayed in the Crosscutting Concepts—Grade 4 chapter for information on how to engage students with the concept of patterns.
In these three examples, students are working with patterns. Regardless of which module is taught first, the other experiences can be connected back to it. For example, if students have worked with patterns in the **Energy Module** and are working in the **Environments Module**, make a connection between the different pattern of the waves and the location of different plants. Questions such as, “Thinking about patterns, how are the waves similar to the location of the plants? How did we compare the waves? If we compare the characteristics of one wave with the characteristics of another, can we compare the characteristics of the areas where the <plant type> is growing? How can we make predictions. Why are patterns helpful in science?”
Cause and Effect: Mechanism and Explanation

When students recognize patterns in phenomena, they begin to ask questions related to those patterns. What causes the ball to always roll down the hill? Why does the Sun come up over that hill every morning? Why do the leaves fall off some trees in the fall but not others? In science, students often observe the effect and then try to determine the cause, like a mystery novel. In engineering, students may try to achieve a specific effect, manipulating the system to uncover how to cause that effect.

Many of the most compelling and productive questions in science are about why or how something happens…. Repeating patterns in nature, or events that occur together with regularity, are clues that scientists can use to start exploring causal, or cause-and-effect, relationships, which pervade all the disciplines of science and at all scales. For example, researchers investigate cause-and-effect mechanisms in the motion of a single object, specific chemical reactions, populations changes in an ecosystem or a society, and the development of holes in the polar ozone layers. (A Framework for K–12 Science Education, 2012, page 87)

Capabilities of students. In grades 3–5, students routinely identify and test causal relationships and use these relationships to explain change. They understand that events that occur together with regularity might or might not signify a cause-and-effect relationship. (Next Generation Science Standards, Appendix G, 2013, page 83)

Introducing cause and effect. The introduction of cause and effect often begins with the effect; students make observations or recognize a pattern, and then ask “How did that happen?” or “Why did that happen?” They are thinking about what caused the observable effects. Those questions can often be rephrased to focus students on the relationship.

Here is an introduction to cause and effect, using a student’s observation.

[Student’s name] said, “The ball rolls very fast sometimes. Sometimes it rolls slowly.” You observed that happen. In science, we call those outcomes effects. A ball rolling fast is one effect. We can think about what caused the ball to roll fast. When we figure out what made the ball roll fast (effect), we know the cause.

➤ What causes how fast the ball rolls?
General strategies for cause and effect.

- Have students identify cause and effects in their everyday life. For example, When I drop a can of soda (cause), the soda sprays out when I open it (effect).
- Start an Effect-and-Cause and a Cause-and-Effect poster. Often in science students identify an effect (an outcome of an investigation) first and then try to determine the cause, such as the speed and distance a ball rolls. Other times, students manipulate the cause and observe the effect, such as what happens (the effect) when I roll the ball from a high position.

Sentence frames for cause and effect.

- When I <cause>, I notice <effect>.
- If I want <effect>, I need to <cause>.
- I wonder what the effect would be if ______ .
- I think ______ is causing ______ .
- I predict <effect> will happen when I <cause>.

Taking it further.

- Have students discuss how they could test if an effect (observation) is the result of (caused by) a certain action. Guide them through the process of experimental design to test their predictions.
- Discuss why scientists and engineers look for cause-and-effect relationships. Ask students how the cause-and-effect relationship helped them understand more about a phenomenon, such as a plant growth.

Grade-level examples. In the Soils, Rocks, and Landforms Module, Investigation 1, Part 2, students investigate rocks breaking into smaller pieces. They describe the simple cause-and-effect relationships resulting in smaller rocks. Students hit rocks against each other in a plastic jar and observe the effect. They can consider what happens in nature with rocks. This is a good opportunity to introduce the sentence frame “When <cause> happens, the effect is <observed effect>. This serves as a claim that students can support with data.

In the Energy Module, students observe the phenomenon of dim lightbulbs and try to determine the cause. Students set up different circuits, series and parallel. Students determine each bulb needs a direct pathway to the energy source for the bulb to be brightly lit. Questions can be asked to have students communicate the relationship...
between the intensity of the light and the type of circuit. To take the crosscutting concept a bit further, students can ask cause-and-effect questions, potentially leading, in the next investigation part, to the cause-and-effect relationship between circuits and broken lightbulbs.

Later in the **Energy Module**, Investigation 5, Part 3, students are asked to look at cause and effects of solar cells and a motor. During a sense-making discussion, students discuss what is causing the motor to turn quickly or slowly. They observe the effect and determine the cause (orientation of solar cell to the light). Next, students change the type of circuit used (cause) in order to observe any change in motor speed (effect). A table summarizing these cause-and-effect data can be created to aid in their answers to the focus question.

**Connections between modules.** In the **Soils, Rocks, and Landforms Module**, students observe the effects of chemical weathering on different types of rocks. In the **Energy Module**, students examine the cause-and-effect relationships of types of materials used in a circuit, such as metal and wood, and observe the effect on a motor. In the **Environments Module**, students examine the salt tolerance of different plants. The salt water is the cause of the effect, in this case, reduced plant growth or death.

When beginning to look at cause-and-effect relationships in a second module, make connections to those relationships established in the first. For example, when looking at the cause-and-effect relationships for salt tolerance, ask students to recall the relationships from the **Energy Module**. How could they use what they learned about testing conductors and insulators to find out more about salt tolerance? Have students look back in their notebooks for how they tested those relationships, they changed the cause (object used in the circuit) and observed the effect. They looked at all those that were successful to determine the cause. They can water the plants with salt water (cause) and observe the effect on the different plants. Increase the level of student independence by encouraging students to revisit cause-and-effect relationships and looking at how they tested, analyzed, and communicated those relationships to make explanations.
Scale, Proportion, and Quantity

In science, quantifying is crucial for observation and understanding of quantity and scale. Length, mass, time, temperature, force, and other measurements have magnitude and require units. Those units are necessary as students begin to record quantifiable data.

In thinking scientifically about systems and processes, it is essential to recognize that they vary in size (e.g., cells, whales, galaxies), in time span (e.g., nanoseconds, hours, millennia), in the amount of energy flowing through them (e.g., lightbulbs, power grids, the Sun), and in the relationships between the scales of these different quantities. The understanding of relative magnitude is only a starting point (A Framework for K–12 Science Education, 2012, page 89).

Capabilities of students. In grades 3–5, students recognize that natural objects and observable phenomena exist from the very small to the immensely large. They use standard metric units to measure and describe physical quantities such as mass, time, temperature, and volume (Next Generation Science Standards, Appendix G, 2013, page 84).

Introducing scale, proportion, and quantity. In grades 3–5, as students are making observations, they often start with comparative words, such as more, bigger, hotter, and faster. When these words are used, you can introduce quantity and scale. For example, when students describe that one ball traveled farther, you might say,

Many of you observed two types of materials in the earth materials, clay and sand. You noticed the clay went farther than the sand. When scientists collect data, they want to be accurate. They measure the distance the materials traveled. When scientists measure, they report the distance using numbers and units. Since the sand traveled part of the way down the stream table, we might use centimeters as the unit to measure. If the sand traveled down an actual river, we might use kilometers as the unit. Scientists need to think about what units will be the most useful for their observation. We can think about that as a type of scale.

General strategies for scale, proportion, and quantity.

• Start with focusing students on observations in which they make comparisons. For example, if they are observing the length of plant growth, they could arrange those observations in order from shortest to longest. As they make additional observations, those can be added to the data.

• Ask students if they wanted to compare their plant to those from a different class, how would they know whose are taller?
Crosscutting Concepts—Grade 4

- Have students create posters for what units can be used in their measurements. For example, students could illustrate three different distances that could be measured using centimeters, meters, and kilometers. Similar posters could be made for mass and fluid volume.

- Help students improve the proportion in their observations by having them critique illustrations you make, such as a stream table. Introduce conventions about recording observations of different sized objects. When drawing very small objects, students might draw their observations as if they were looking through a hand lens.

**Sentence frames for scale, proportion, and quantity.**

- We should use <metric units> to measure <objects>.
- If I compare the (size, speed, temperature, etc.), the ______.
- The amount of ______ is ______ than the amount of ______.
- We should measure ________ to figure out the relationship.

**Taking it further.**

- Ask students to scale up or down their thinking about phenomena. For example, after testing the force needed to break the force of two magnets with no space in between, ask them what would happen if they used stronger magnets.

- Have students share various ways to record observations of phenomena that are very small or very large.

- Discuss when scientists might measure something very precisely (distance an object moves) and when they might estimate (the number of plants in a section of the schoolyard.)

- Discuss why scale is important for scientists and engineers. For example, when designing a new car body, they might need a smaller version in order to test their ideas quickly. Erosion, deposition, and volcanic eruptions can be tested in smaller scales when trying to determine possible solutions.

**Grade-level examples.** In the Soils, Rocks, and Landforms Module, Investigation 3, Part 2, students have worked with a foam-model of an actual mountain, drawn a topographic map of the mountain, and created a profile of the same landform. These provide information on a much smaller scale than the actual mountain, but they all use the same contour interval. However, when they compare the contour interval on the USGS topographic map, they notice a different interval. While the scale for the USGS map is different, they both provide similar information.
Crosscutting Concepts—Grade 4

Systems and System Models

By the time students enter school, they have experienced countless systems—phones, cars, toys, and the various ecosystems (urban park, seashore, woods). The interactions between the parts of a system and what enters and leaves the system can be explored, represented, and discussed with students.

Systems and system models are useful in science and engineering because the world is complex. It is helpful to isolate and focus on a limited portion of the grand system and construct a simplified model of it.

To do this, scientists and engineers imagine an artificial boundary between the system in question and everything else. They then examine the system in detail while treating the effects of things outside the boundary as either forces acting on the system or flows of matter and energy across it. Yet the properties and behavior of the whole system can be very different from those of any of its parts, and large systems may have emergent properties, such as the shape of a tree, that cannot be predicted in detail from knowledge about the components and their interactions (A Framework for K–12 Science Education, 2012, page 92).

Capabilities of students. In grades 3–5, students understand that a system is a group of related (interacting) parts that make up a whole and can carry out functions its individual parts cannot. They can also describe a system in terms of its components and their interactions (Next Generation Science Standards, Appendix G, 2013, page 85).

Introducing systems and system models. Start with a visible system students have worked with, such as a lightbulb, wires, and D-cell (from the Energy Module). If possible, draw an example on chart paper. Ask students to identify the parts they see and label the drawings. Introduce system.

A system is made up of parts that work together or interact, like this cart system. Scientists study systems to find out how they work and what happens (effects) when something in the system changes (causes). Let’s think about how the parts of our system work together or interact.

For students in grades 3–5, indicate how something that is part of the system or outside of the system can change. For example, the hands holding the wire can be part of the system or not, depending on the desire of the investigator. Scientists often describe what is and is not part of the system.

Identify a particularly important part (component or structure are also acceptable words to use) of the system. Ask students to identify how that part works with or interacts with other parts of the system. Ask,
What properties of the component make it suitable for its function in the system?

In this particular case, the properties of the wires that make them function in this system become clearer over the next few weeks. If students need more scaffolding with how the parts work together, have them analyze a familiar system.

General strategies for systems and system models.

- Start with focusing students on a scientific illustration of a system and identifying the parts. Have students discuss how two particular parts work together rather than all the parts. Continue the discussion by adding how a third part works with the other two.
- Have students make posters with different systems they have studied in earth, physical, and life science.
- Discuss with students what might happen to the system if a particular part is removed, such as the roots of a plant.

Sentence frames for systems and system models.

- The parts of the system are ______.
- <One part> works with <second part> by ______.
- This system does not include ______.
- The function of this system is ______.
- This system helps me understand ______.

Taking it further.

- Introduce more complex systems as the year progresses. Some systems are made of subsystems. This adds a layer of complexity so you might do a think aloud to model how a complex system can be studied easier by focusing on one specific subsystem at a time.
- Create a list of parts and objects in which some are useful in understanding the system and others are extraneous. For example, when looking at the isopod habitat as a system, the basin might be included but the table the basin sits on isn’t necessary for understanding the isopod habitat system. Have students sort the list into parts that should be parts of the system.
- Discuss why scientists and engineers study systems. Ask students how focusing on a system helps them understand more about the phenomenon.
**Grade-level example.** In the fourth-grade Environments Module, Investigation 2, Part 1, students construct an aquatic environment for goldfish and a separate one for guppies. They add gravel, elodea, snails, and *Gammarus* to the environment and observe the interaction between the parts. Students are introduced to ecosystem as the interaction between the organisms in the environment. The goldfish, elodea, snails, and other parts make up the system. This provides an opportunity for students to discuss what the system under study actually is. Asking questions such as, “What are we trying to determine?” Students might think the nonliving factors are not important to the system when studying the interactions between organisms, only the living ones are. This is accurate, if they are looking at a food chain. Later in the module, nonliving factors, such as amount of the salt in the water, is a crucial part of the system needed for some organisms.

In Part 2 of the same investigation, students have worked with organism cards and made a concept grid about the function of animal structures. Students are asked what structures animals need to get oxygen. These structures are the parts of the animals breathing system. While students can identify the internal and external structures, they can be asked how they work together as a system. The speculations on the interaction between the internal and external structures are researched and presented on posters.

**Connections between modules.** In the Soils, Rocks, and Landforms Module, students work with a stream-table system to model how weathered pieces of rock move from place to place. They make observations about the cause-and-effect relationships in the system, such as the steeper the slope, the deeper the canyons. In the Energy Module, students construct a long-string of lights, a system, to analyze what the effect of one of the parts of the system, a bulb, stops functioning. In the Environments Module, students design an environment to meet the basic needs of an isopod. As students work with their first system, they establish the meaning of a system and a process of representing the system using drawings and labels of the parts to explain how they interact. In the second system, have students revisit their notebook entry for the first system. Have students discuss how they described the first system and how they can use that to describe the second system. When making connections between specific systems, focus on how the parts interact with each other, such as which parts hold the system together, which enable movement, etc.
Energy and Matter: Flows, Cycles, and Conservation

Matter is all around us. Solids, liquids, and gases make up the world we live in and interact with. Students’ thinking might initially be limited to identifying the states of matter, not the flow of matter within and through systems. Energy, also within and flowing through systems, makes things happen. Older students can begin to consider how energy moves (transfers).

The crosscutting concept of energy and matter is connected to the disciplinary core ideas addressing energy and matter. While the core ideas are focused on building student understanding of the structure and function of matter, energy, and their interactions, the crosscutting concepts focus more on the effects (matter and energy) and conservation (matter only at the elementary level).

One of the great achievements of science is the recognition that, in any system, certain conserved quantities can change only through transfers into or out of the system. Such laws of conservation provide limits on what can occur in a system, whether human built or natural….The supply of energy and of each needed chemical element restricts a system’s operation—for example, without inputs of energy (sunlight) and matter (carbon dioxide and water), a plant cannot grow. Hence, it is very informative to track the transfers of matter and energy within, into, or out of any system under study.

... Young children are likely to have difficulty studying the concept of energy in depth—everyday language surrounding energy contains many shortcuts that lead to misunderstandings. For this reason, the concept is not developed at all in K–2 and only very generally in grades 3–5. Instead, the elementary grades focus on recognition of conservation of matter and of the flow of matter into, out of, and within systems under study (A Framework for K–12 Science Education, 2012, pages 94–96).

Capabilities of students. In grades 3–5, students learn matter is made of particles and energy can be transferred in various ways and between objects. Students observe the conservation of matter by tracking matter flows and cycles before and after processes and recognizing the total weight of substances does not change (Next Generation Science Standards, Appendix G, 2013, page 86).

Introducing energy and matter. Students in third grade examine how matter is conserved when making mixtures, so the movement of matter is familiar territory to students in fourth grade. Energy transfer is more elusive. The Energy Module has students work with several different systems in which students can begin to explore energy transfer. It is recommended to use the Energy Module to introduce this concept. In the Investigations Guide students are introduced to ways energy moves from place to place by using a lightbulb system. Introduce the flow of energy.
Scientist often think about how energy moves in a system. In this system, the energy is transferred when there is an electric current flowing, but we can’t see the electric current. We can see evidence of an electric current when the bulb lights. Light is evidence of energy transfer. This is a very simple flow of energy from one place to another.

Scientists study complex systems to find out how energy moves into, around, and out of a system. For example, if they are studying a system and the available energy of the D-cell is decreasing, they would need to figure where the energy is leaving the system, in this case, light and a small amount of heat. I wonder how the energy is moved from the D-cell to the light bulb?

For students in grades 3–5, focus and provide support on the movement of energy and what students can observe using their senses. In later grades, students will consider energy movement in greater depth.

**General strategies for energy and matter.**

- Asking questions to focus students’ attention on where energy is during a particular time can aid in developing this concept. For example,

  ➤ Where is the energy at the start? Where does the energy go next? Does the energy stay in the system or go to another system at the end? Does any new energy enter the system?

- Visually represent the movement of matter or energy using arrows or a series of drawings.

- Create a class chart of systems and evidence of energy transfer. (See the sidebar for an example from the Energy Module.)

- A good system for students to study is the physical classroom. Students being a part of the matter or energy in the room, ask students to think of when matter enters the room, how matter moves in the room, and when and why the matter leaves the room. Ask students to make connections between the classroom system and the scientific system they are investigating.

**Sentence frames for energy and matter.**

- The matter in the system is ________.
- The matter starts ________. Next, the matter ________.
- The matter changes when ________.
- The energy transfers from ________ to ________.
- For this system to function, the energy (or matter) needs to ________.

**NOTE**

The lightbulb system can be very confusing for students. Electric current is flowing thought the whole system and remains in the system, however, some energy is transferred out of the system by light. Students often equate energy and electricity. Electric current is only one way energy can be transferred; students work with other ways throughout the module.
Taking it further.

- Discuss why scientists and engineers study the movement of matter. Ask students how focusing on matter could help them understand more about the system.

Grade-level example. In the Energy Module, Investigation 3, Part 3, students work with a telegraph. During the discussion, students are asked to find different evidence that energy is being transferred in the system. Later in Investigation 4, Part 3, students determine how energy is transferred during collisions. See the Sense-Making Discussions for Three-Dimensional Learning chapter for more information.

In the Environments Module, Investigation 2, Part 2, students work with feeding relationships. A crucial part of the food chain are the producers. The producers are the primary source of energy and matter in the system.

Connections between modules. In both instances, energy (and matter in the food chain) is being transferred from one place to another. During the first experience of analyzing a system to determine the movement of energy, focus students on ways to represent the movement using arrows or a series of images. For electric circuits, use a different color arrow than used to show the flow of electricity. In the second experience, ask students how the movement of energy in this system is similar to the movement of energy in the other system. Additionally, make connections to the ways students have previously recorded the movement of matter (or energy).
Structure and Function

Students observe many different structures—the school playground equipment, buildings, and furniture. They readily accept these designed systems as structures. The leg of a beetle, the mouth of a river, and even the hair on your head are also structures; they can be viewed as components, parts, or subsystems that can be broken up into even more subsystems, depending on the scale used for analysis. Both designed and natural structures perform functions. These functions depend on the properties of the objects.

Herein lies a vocabulary challenge. *Structure* has multiple meanings. *Structure* can refer to a system or object, such as a building or leg of a beetle. Structure can also refer to the form or arrangement of the parts of a system and their properties. The shape and stability of structures of natural and designed objects are related to their function(s).

*The functioning of natural and built systems alike depends on the shapes and relationships of certain key parts as well as on the properties of the materials from which they are made.*

Understanding how a bicycle works is best addressed by examining the structures and their functions at the scale of, say, the frame, wheels, and pedals. However, building a lighter bicycle may require knowledge of the properties (such as rigidity and hardness) of the materials needed for specific parts of the bicycle. In that way, the builder can seek less dense materials with appropriate properties; this pursuit may lead in turn to an examination of the atomic-scale structure of candidate materials. As a result, new parts with the desired properties, possibly made of new materials, can be designed and fabricated (A Framework for K–12 Science Education, 2012, pages 96–97).

**Capabilities of students.** In grades 3–5, students learn that different materials have different substructures, which can sometimes be observed, and that substructures have shapes and parts that serve functions (Next Generation Science Standards, Appendix G, 2013, page 87).

**Introducing structure and function to students.** When students are looking at a particular object or organism, call for attention. Say,

> You have been observing <object, system, or organism>. I want you to look at <specific part of the object/organism>. Scientists call the parts of objects and organisms structures. Structures have properties.

Have students look at the structure they are studying. Ask,

> What are the properties of the structure that make it suitable for its function in the system?
When scientists and engineers look at objects, systems, and organisms, they often try to figure out what the object or part of an object is doing. You might think of it as they are trying to figure out the job of the structure. That is called the function. The function is what the structure does in a system or an organism.

**General strategies for structure and function.**

- Start with some examples of functions of common objects in the classroom. For example,

  > **What is the function, or job, of your shoelace?**

- Once students have identified the function of a structure (object or component), ask what would happen if the structure (form or property) of the object were to change. For example,

  > **If shoelaces were made out of a different material like a gummy bear or a stiff metal wire, how would the function change?**

- Ask students to identify what functions of a designed object, such as a telegraph, are important to make the object work. What shapes or properties does the core need to have?

**Sentence frames for structure and function.**

- The shapes I see are ______.
- The structures make the system work by ______.
- An important structure of this object is ______.
- For this part, we had to use something <property> so it would ______.

**Taking it further.**

- Ask students to identify an important structure of what they are observing, such as the parts of critter found in leaf litter. Have them identify the function of that structure. If the function of the antennae is to help find food, what properties do they need to have?

- Discuss why scientists and engineers study functions of objects. How might knowing specific properties of an object be helpful when designing an object.
**Grade-level examples.** In the *Environments Module*, Investigation 1, Part 3, students create a concept grid to record the structures, both internal and external, and their function of animals. When working with this type of structure/function, a chart could be created to list the structures and corresponding functions. Alternatively, a drawing of the animal can be labeled with the structures in one color and their functions in another color.

In Investigation 2, Part 2, students revisit their concept grid and add additional animals from other environments. Students then focus on the basic need of most animals for oxygen, and they begin to gather information and compare how different structures found in different kinds of animals function to provide animals with oxygen—lungs, gills, spiracles, skin.

**Connections between modules.** In the *Soils, Rocks, and Landforms Module*, students look for earth materials in use. As they observe how humans use earth materials they look at how the structure of the earth materials function. In the *Environment Module*, students look at the function of parts of a brine shrimp. In both these instances, students are working on determining the functions. Students will need support to identify the function of some structures and determining what are the necessary properties of the structures.
Stability and Change

Students are very adept at noticing changes that impact their lives. The arrangement of the classroom, the weather, and the water level in the creek near school are all things that can change. However, things or systems that are stable, or unchanging at a certain level are initially uninteresting for students. Picture an outdoor location, a small system consisting of a rock sitting under a tree in the grass. The location and general appearance of the rock is stable. It doesn’t move and still ‘looks like a rock.’ Over the course of a year, the rock’s appearance changes, water might make it look darker, moss may form on the surface. The leaves around the rock move, the grass may wither but the rock remains firmly positioned and generally unchanged. Students can consider what causes some things to change, but others to remain stable.

Stability denotes a condition in which some aspects of a system are unchanging, at least at the scale of observation. Stability means that a small disturbance will fade away—that is, the system will stay in, or return to, the stable condition. Such stability can take different forms, with the simplest being a static equilibrium, such as a ladder leaning on a wall. By contrast, a system with steady inflows and outflows (i.e., constant conditions) is said to be in dynamic equilibrium. For example, a dam may be at a constant level with steady quantities of water coming in and out. . . . A repeating pattern of cyclic change—such as the Moon orbiting Earth—can also be seen as a stable situation, even though it is clearly not static (A Framework for K–12 Science Education, 2012, page 98).

Capabilities of students. In grades 3–5, students measure change in terms of differences over time, and observe that change can occur at different rates. Students learn some systems appear stable, but over long periods of time, they will eventually change (Next Generation Science Standards, Appendix G, 2013, page 88).

Introducing stability and change. For students to consider stability and change, they need to observe changes or lack of changes over time. When you hear “nothing is happening,” “it’s balanced,” or “things are really different than they were yesterday,” gather students for a discussion.

Ask student what they notice. Listen to their responses. Note what they are reporting changed or did not change. If students are reporting only changes, ask if any part is staying the same. Note: For some designed systems, they might report that a part of a design moves when you touch it, but the object still functions.

When scientists and engineers make observations, they notice when something changes. You observed <reference specific change>.
What are other examples of changes? [Weather, falling leaves, etc.]

Scientists and engineers also notice when nothing seems to change, such as <reference the reported nonchange>. Things that are stable seem not to change. Whether things are stable or stay the same, change slowly or change quickly, scientists are curious about what causes those changes or effects.

General strategies for stability and change.

• Create a poster of an event or a phenomenon in which there is an observable change. Have students identify how long the change takes. Does it happen quickly or over a few weeks?

• Discuss with students how they might record changes that happen over time in their notebook.

• A good system for students to study is the physical classroom. What changes happen in the classroom? How often does the change happen? Is there anything in the class that remains the same for the whole year?

Sentence frames for stability and change.

• Something that is changing is ______ .

• The change happens <length of time.>

• I wonder if the change will ______ .

• I think the change might be caused by ______ .

• If <specific change> happens, it means ______ .

Taking it further.

• Discuss why scientists and engineers study how things change or stay the same. Ask students how focusing on a change could help them understand more about the phenomenon.

Grade-level example. In the Soils, Rocks, and Landforms Module, students look at rapid changes due to natural causes, such as earthquakes. Ask questions that help them to discover that changes to Earth’s surface can happen quickly or take a long time, depending on an number of variables. The difference in time for changes to take place is an important part of this crosscutting concept.

Connections between modules. In the Environment Module, students look at the stability and changes in a deer population over 5 years. In this instance and the previous example, students are working on determining the changes that occur and the time for those changes to take place. As students progress, students can determine that some things can be stable for a very long time and change very quickly.
CROSSCUTTING-CONCEPT QUESTIONS

This table contains sample crosscutting-concept questions that can be incorporated into a sense-making discussion. For questions that connect with science and engineering practices as well, the connection appears in parenthesis.

<table>
<thead>
<tr>
<th>Patterns</th>
<th>Cause and effect</th>
<th>Scale, proportion, and quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What patterns do I see when I observe ______?</td>
<td>• What did you observe? What do you think caused that to happen? (Analyzing and interpreting data)</td>
<td>• What should we measure during our test? (Planning and carrying out investigations)</td>
</tr>
<tr>
<td>• Is there a pattern that repeats in this system? Is there a shape or structure that I keep seeing?</td>
<td>• How would you describe the relationship between the cause and the effect? (Constructing explanations)</td>
<td>• What units should we use? (Planning and carrying out investigations)</td>
</tr>
<tr>
<td>• What questions do I have about these patterns? (Asking questions)</td>
<td>• What can you change about your system to cause &lt;desired effect&gt; to happen? (Designing solutions)</td>
<td>• What do we need to do to make these observations or measurements? (Planning and carrying out investigations)</td>
</tr>
<tr>
<td>• How can I show or represent these patterns in my model? (Developing and using models)</td>
<td>• What is causing the pattern? What does the pattern tell me about (the system or phenomenon)? (Designing solutions)</td>
<td>• What relationships do you see in the measurements? (Analyzing and interpreting data)</td>
</tr>
<tr>
<td>• What can I do to test these patterns? (Planning and carrying out investigations)</td>
<td>• How can I use these patterns as evidence to support my claims or reasoning about the system or phenomenon? (Engaging in argument from evidence)</td>
<td>• How can I use a model to test my design? (Designing solutions)</td>
</tr>
<tr>
<td>• How can I record these patterns in my notebook? (Analyzing and interpreting data)</td>
<td>• How is the pattern the same or different than what I read about? How can I describe my pattern to someone else? (Obtaining, evaluating, and communicating information)</td>
<td></td>
</tr>
</tbody>
</table>

### Crosscutting Concept Questions

<table>
<thead>
<tr>
<th>Systems and system models</th>
<th>Energy and matter</th>
<th>Structure and function</th>
<th>Stability and change</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What is the function of the system?</td>
<td>• What matter is part of this system?</td>
<td>• What particular shapes or structures are observed in this system at this scale? (Planning and carrying out investigations)</td>
<td>• What changes do I notice? How quickly is the change happening? (Analyzing and interpreting data)</td>
</tr>
<tr>
<td>• What are the parts or components of the system? (Developing and using models)</td>
<td>• What matter comes into the system?</td>
<td>• What roles do these structures play in the functioning of the system? (Developing and using models)</td>
<td>• What can I investigate more closely to recognize the cause of a change? (Planning and carrying out investigations)</td>
</tr>
<tr>
<td>• What is the role &lt;job, function&gt; of each part?</td>
<td>• What matter moves or changes in the system?</td>
<td>• What design features of appearance and structure are important? (Defining problems)</td>
<td>• What changes would cause it to become unstable or to fail? (Developing and using models)</td>
</tr>
<tr>
<td>• How does &lt;one part&gt; work with &lt;another part&gt;?</td>
<td>• What matter goes out of the system?</td>
<td>• What properties of the components are important for the function of this design? (Designing solutions)</td>
<td>• How can I improve the stability of my design? (Designing solutions)</td>
</tr>
<tr>
<td>• How can we develop a model of this system?</td>
<td>• What does energy do in the system?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What is not part of the system?</td>
<td>• How is energy moving in the system?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What happens to the system when _____ is removed?</td>
<td>• How does energy enter the system?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What system or systems do we need to model in order to explain this phenomenon? (Developing and using models)</td>
<td>• How does energy leave the system?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• What matter flows into, out of, and within the system? What physical and chemical changes occur during this phenomenon? (Developing and using models)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• What energy transfers occur into, out of, or within the system? What transformations of energy are important to its operation? (Developing and using models)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• What inputs are needed for the system to function? What are the desired outputs of the system? (Defining problems)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## CROSSCUTTING CONCEPTS OPPORTUNITIES IN FOSS

This is a complete listing of every instance where a crosscutting concept is called out in the sidebar of the FOSS Investigations Guide. The ones in bold are the grade-level examples described in this chapter.

<table>
<thead>
<tr>
<th>Grades 3–5 Crosscutting Concept Statements*</th>
<th>Soils, Rocks, and Landforms Module</th>
</tr>
</thead>
</table>
| Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena. | Inv 1, Part 1, Step 4: Return to class  
Inv 1, Part 1, Step 9: Discuss materials that make up soils  
Inv 1, Part 1, Step 14: Have a sense-making discussion  
Inv 2, Part 1, Step 7: Guide the analysis of data  
Inv 3, Part 3, Step 3: Discuss the maps |
| Patterns of change can be used to make predictions. | Inv 1, Part 1, Step 22: Share notebook entries  
Inv 1, Part 3, Step 15: Have a sense-making discussion  
Inv 1, Part 4, Step 9: Observe soil samples  
Inv 1, Part 4, Step 11: Discuss further separation of the soil samples  
Inv 1, Part 4, Step 14: Have a sense-making discussion  
Inv 2, Part 2, Step 23: Assess progress: performance assessment  
Inv 2, Part 3, Step 9: Have a sense-making discussion  
Inv 3, Part 3, Step 3: Discuss the maps |
| Patterns can be used as evidence to support an explanation. |  |
| Events that occur together with regularity might or might not be a cause-and-effect relationship. | Inv 1, Part 2, Step 15: Share notebook entries  
Inv 1, Part 3, Step 15: Have a sense-making discussion  
Inv 1, Part 3, Step 16: Introduce chemical weathering  
Inv 1, Part 3, Step 24: Share notebook entries  
Inv 2, Part 1, Step 21: Share notebook entries  
Inv 2, Part 2, Step 23: Assess progress: performance assessment  
Inv 2, Part 3, Step 7: Simulate erosion and deposition  
Inv 2, Part 4, Step 6: Discuss the video with the class  
Inv 3, Part 4, Step 4: Activate prior knowledge |

*From Next Generation Science Standards, Volume 2, Appendixes, pages 92-95
<table>
<thead>
<tr>
<th>Energy Module</th>
<th>Environments Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. 2, Part 1, Step 12: Have a sense-making discussion</td>
<td>Inv. 4, Part 2, Step 11: Look for plant patterns</td>
</tr>
<tr>
<td>Inv. 2, Part 1, Step 16: Discuss iron detecting and review vocabulary</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 1, Step 19: Assess progress: notebook entry</td>
<td></td>
</tr>
<tr>
<td>Inv. 4, Part 3, Step 7: Discuss a motion experiment</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 5: Define wave</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 18: Assess progress: notebook entry</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 25: Share notebook entries</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 7: Debrief the group discussions</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 1, Step 12: Have a sense-making discussion</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 3, Step 11: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 3, Step 13: Make predictions using the graph</td>
<td></td>
</tr>
<tr>
<td>Inv. 3, Part 2, Step 6: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Inv. 4, Part 2, Step 11: Introduce potential energy and kinetic energy</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 9: Discuss the wave observation</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 13: Review waves with spring toy</td>
<td></td>
</tr>
<tr>
<td>Inv. 4, Part 2, Step 11: Look for plant patterns</td>
<td></td>
</tr>
</tbody>
</table>
## Crosscutting Concepts—Grade 4

<table>
<thead>
<tr>
<th>Grades 3–5 Crosscutting Concept Statements</th>
<th>Soils, Rocks, and Landforms Module</th>
</tr>
</thead>
</table>
| **Cause-and-effect relationships are routinely identified, tested, and used to explain changes.** | Inv 1, Part 2, Step 6: Observe results  
Inv 1, Part 2, Step 13: Answer the focus question  
Inv 1, Part 2, Step 15: Share notebook entries  
Inv 1, Part 3, Step 7: Assess progress: performance assessment  
Inv 1, Part 3, Step 15: Have a sense-making discussion  
Inv 1, Part 3, Step 16: Introduce chemical weathering  
Inv 1, Part 3, Step 24: Share notebook entries  
Inv. 2, Part 1, Step 7: Guide the analysis of data  
Inv. 2, Part 1, Step 12: Have a sense-making discussion  
Inv. 2, Part 1, Step 21: Share notebook entries  
Inv. 2, Part 2, Step 6: Guide the recording of the stream-table run  
Inv. 2, Part 2, Step 13: Have a sense-making discussion  
Inv. 2, Part 2, Step 16: Discuss erosion, deposition, and soils  
Inv. 2, Part 2, Step 23: Assess progress: performance assessment  
Inv. 2, Part 3, Step 7: Simulate erosion and deposition  
Inv. 2, Part 3, Step 12: View online activity  
Inv. 2, Part 3, Step 13: Share notebook entries  
Inv. 2, Part 4, Step 6: Discuss the video with the class  
Inv. 2, Part 4, Step 12: Have a sense-making discussion  
Inv. 3, Part 4, Step 4: Activate prior knowledge  
Inv. 4, Part 2, Step 12: Observe the cured concrete |
### Energy Module

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. 1, Part 1, Step 8</td>
<td>Introduce system and electricity</td>
</tr>
<tr>
<td>Inv. 1, Part 1, Step 9</td>
<td>Introduce notebook sheet 1</td>
</tr>
<tr>
<td>Inv. 1, Part 1, Step 17</td>
<td>Assess progress: notebook entry</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 7</td>
<td>Add to the energy chart</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 11</td>
<td>Introduce conductor and insulator</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 18</td>
<td>Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 22</td>
<td>Assess progress: notebook entry</td>
</tr>
<tr>
<td>Inv. 1, Part 3, Step 27</td>
<td>Assess progress: response sheet</td>
</tr>
<tr>
<td>Inv. 1, Part 3, Step 30</td>
<td>Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 1, Part 4, Step 4</td>
<td>assess progress: performance assessment</td>
</tr>
<tr>
<td>Inv. 2, Part 1, Step 24</td>
<td>Discuss findings</td>
</tr>
<tr>
<td>Inv. 2, Part 2, Step 4</td>
<td>Introduce bar magnets and poles</td>
</tr>
<tr>
<td>Inv. 2, Part 2, Step 15</td>
<td>Facilitate sense-making with two demonstrations</td>
</tr>
<tr>
<td>Inv. 2, Part 2, Step 23</td>
<td>Assess progress: response sheet</td>
</tr>
<tr>
<td>Inv. 2, Part 3, Step 7</td>
<td>Introduce spacers</td>
</tr>
<tr>
<td>Inv. 2, Part 3, Step 13</td>
<td>Make predictions using the graph</td>
</tr>
<tr>
<td>Inv. 2, Part 3, Step 20</td>
<td>Discuss “Magnificent Magnetic Models”</td>
</tr>
<tr>
<td>Inv. 3, Part 1, Step 14</td>
<td>Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 3, Part 2, Step 6</td>
<td>Assess progress: performance assessment</td>
</tr>
<tr>
<td>Inv. 3, Part 3, Step 19</td>
<td>Troubleshoot problems</td>
</tr>
<tr>
<td>Inv. 4, Part 2, Step 11</td>
<td>Introduce potential energy and kinetic energy</td>
</tr>
<tr>
<td>Inv. 4, Part 2, Step 19</td>
<td>Discuss the reading</td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 4</td>
<td>Discuss water observation</td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 9</td>
<td>Discuss the wave observation</td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 13</td>
<td>Review waves with spring toy</td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 18</td>
<td>Assess progress: notebook entry</td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 25</td>
<td>Share notebook entries</td>
</tr>
<tr>
<td>Inv. 5, Part 2, Step 8</td>
<td>Return to class</td>
</tr>
<tr>
<td>Inv. 5, Part 2, Step 13</td>
<td>Share student-created challenges</td>
</tr>
<tr>
<td>Inv. 5, Part 2, Step 30</td>
<td>Discuss the reading</td>
</tr>
<tr>
<td>Inv. 5, Part 3, Step 6</td>
<td>Deepen the inquiry</td>
</tr>
<tr>
<td>Inv. 5, Part 3, Step 7</td>
<td>Have a sense-making discussion</td>
</tr>
</tbody>
</table>

### Environments Module

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. 1, Part 1, Step 12</td>
<td>Design an experiment</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 11</td>
<td>Observe short-run results</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 12</td>
<td>Go for long-run results</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 22</td>
<td>Assess progress: performance assessment</td>
</tr>
<tr>
<td>Inv. 3, Part 2, Step 16</td>
<td>Have students use a graphic organizer</td>
</tr>
<tr>
<td>Inv. 3, Part 2, Step 22</td>
<td>Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 3, Part 3, Step 16</td>
<td>Share notebook entries</td>
</tr>
<tr>
<td>Inv. 4, Part 1, Step 12</td>
<td>Assess progress: performance assessment</td>
</tr>
<tr>
<td>Inv. 4, Part 1, Step 40</td>
<td>Have a sense-making discussion</td>
</tr>
<tr>
<td>Grades 3–5 Crosscutting Concept Statements</td>
<td>Soils, Rocks, and Landforms Module</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
</tbody>
</table>
| Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. | Inv. 2, Part 1, Step 7: Guide the analysis of data  
Inv. 3, Part 1, Step 4: Demonstrate how to build a model mountain  
Inv. 3, Part 1, Step 5: Describe the model landform  
Inv. 3, Part 1, Step 14: Compare topographic maps  
Inv. 3, Part 1, Step 15: Notice the slope  
Inv. 3, Part 1, Step 20: Assess progress: notebook entry  
Inv. 3, Part 2, Step 4: Demonstrate drawing a profile  
Inv. 3, Part 2, Step 7: Compare profiles and mountains  
Inv. 3, Part 2, Step 8: Have a sense-making discussion  
Inv. 3, Part 3, Step 5: Assess progress: performance assessment |
| Observable phenomena exist from very short to very long periods. | Inv. 2, Part 1, Step 7: Guide the analysis of data  
Inv. 4, Part 1, Step 6: View video about natural resources  
Inv. 4, Part 1, Step 9: Assess progress: response sheet |
| A system can be described in terms of its components and their interactions. | Inv 1, Part 1, Step 20: Read “What Is Soil?”  
Inv. 2, Part 1, Step 3: Review model  
Inv. 2, Part 1, Step 12: Have a sense-making discussion  
Inv. 2, Part 1, Step 21: Share notebook entries |
<table>
<thead>
<tr>
<th>Energy Module</th>
<th>Environments Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. 1, Part 1, Step 8: Introduce system and electricity</td>
<td>Inv. 1, Part 2, Step 34: Design an isopod environment</td>
</tr>
<tr>
<td>Inv. 1, Part 1, Step 9: Introduce notebook sheet 1</td>
<td>Inv. 1, Part 3, Step 16: Discuss the reading</td>
</tr>
<tr>
<td>Inv. 1, Part 1, Step 17: Assess progress: notebook entry</td>
<td>Inv. 2, Part 1, Step 16: Have a class discussion</td>
</tr>
<tr>
<td>Inv. 1, Part 1, Step 22: Share notebook entries</td>
<td>Inv. 2, Part 1, Step 17: Introduce ecosystem</td>
</tr>
<tr>
<td>Inv. 1, Part 1, Step 23: Engage in argumentation</td>
<td>Inv. 2, Part 2, Step 23: Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 7: Add to the energy chart</td>
<td>Inv. 2, Part 2, Step 26: Discuss basic need for oxygen</td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 22: Assess progress: notebook entry</td>
<td>Inv. 2, Part 3, Step 17: Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 1, Part 3, Step 12: Generate questions</td>
<td>Inv. 3, Part 1, Step 9: Assess progress: performance assessment</td>
</tr>
<tr>
<td>Inv. 1, Part 3, Step 17: Build circuits</td>
<td>Inv. 3, Part 4, Step 12: Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 1, Part 3, Step 27: Assess progress: response sheet</td>
<td></td>
</tr>
<tr>
<td>Inv. 1, Part 4, Step 4: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Inv. 3, Part 1, Step 14: Have a sense-making discussion</td>
<td></td>
</tr>
<tr>
<td>Inv. 3, Part 3, Step 6: Share results</td>
<td></td>
</tr>
<tr>
<td>Inv. 4, Part 1, Step 10: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 13: Review waves with spring toy</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 1, Step 18: Assess progress: notebook entry</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 2, Step 8: Return to class</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 2, Step 13: Share student-created challenges</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 2, Step 21: Assess progress: response sheet</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 2, Step 30: Discuss the reading</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 3, Step 6: Deepen the inquiry</td>
<td></td>
</tr>
<tr>
<td>Inv. 5, Part 3, Step 18: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Grades 3–5 Crosscutting Concept Statements</td>
<td>Soils, Rocks, and Landforms Module</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Energy can be transferred in various ways and between objects.</td>
<td></td>
</tr>
<tr>
<td>Matter is transported into, out of, and within systems.</td>
<td></td>
</tr>
</tbody>
</table>
| Different materials have different substructures, which can sometimes be observed. | Inv. 4, Part 3, Step 5: Assess progress: performance assessment  
Inv. 4, Part 3, Step 10: Have a sense-making discussion  
Inv. 4, Part 3, Step 11: Answer the focus question |
| Substructures have shapes and parts that serve functions. | |
### Energy Module

- Inv. 1, Part 1, Step 15: Start a class energy systems chart
- Inv. 1, Part 1, Step 16: Answer the focus question
- Inv. 1, Part 1, Step 22: Share notebook entries
- Inv. 1, Part 1, Step 23: Engage in argumentation
- Inv. 1, Part 2, Step 7: Add to the energy chart
- Inv. 1, Part 2, Step 11: Introduce conductor and insulator
- Inv. 1, Part 2, Step 22: Assess progress: notebook entry
- Inv. 1, Part 3, Step 27: Assess progress: response sheet
- Inv. 2, Part 2, Step 3: Discuss attract and repel
- Inv. 3, Part 1, Step 14: Have a sense-making discussion
- Inv. 3, Part 2, Step 17: Share notebook entries
- Inv. 4, Part 1, Step 10: Assess progress: performance assessment
- Inv. 4, Part 1, Step 15: Discuss the reading
- Inv. 4, Part 3, Step 13: Analyze the results in terms of energy
- Inv. 5, Part 1, Step 13: Review waves with spring toy
- Inv. 5, Part 1, Step 18: Assess progress: notebook entry
- Inv. 5, Part 2, Step 18: Have a sense-making discussion

### Environments Module

- Inv. 2, Part 2, Step 7: Introduce producer
- Inv. 2, Part 2, Step 19: Introduce a crosscutting concept
- Inv. 2, Part 2, Step 23: Have a sense-making discussion
- Inv. 2, Part 3, Step 26: Discuss the reading
- Inv. 2, Part 2, Step 7: Introduce producer
- Inv. 2, Part 2, Step 19: Introduce a crosscutting concept
- Inv. 2, Part 2, Step 23: Have a sense-making discussion
- Inv. 2, Part 3, Step 26: Discuss the reading
- Inv. 4, Part 1, Step 2: Introduce mealworms
- Inv. 1, Part 1, Step 6: Observe observations
- Inv. 1, Part 1, Step 7: Focus question: How do mealworm structures and behaviors help them grow and survive?
- Inv. 1, Part 1, Step 29: Focus on crosscutting concept
- Inv. 1, Part 2, Step 29: Discuss the reading
- Inv. 1, Part 3, Step 6: Search for critters
- Inv. 1, Part 3, Step 19: Use a concept grid
- Inv. 2, Part 1, Step 4: Study the organisms
- Inv. 2, Part 2, Step 25: Return to concept grid for structures
- Inv. 3, Part 1, Step 16: Discuss survival in saltwater environments
- Inv. 4, Part 3, Step 5: Discuss the video

Crosscutting Concepts—Grade 4
Crosscutting Concepts—Grade 4

<table>
<thead>
<tr>
<th>Grades 3–5 Crosscutting Concept Statements</th>
<th>Soils, Rocks, and Landforms Module</th>
</tr>
</thead>
</table>
| Change is measured in terms of differences over time and may occur at different rates. | Inv. 2, Part 1, Step 7: Guide the analysis of data  
Inv. 2, Part 2, Step 16: Discuss erosion, deposition, and soils  
Inv. 2, Part 3, Step 9: Have a sense-making discussion  
Inv. 2, Part 3, Step 12: View online activity  
Inv. 2, Part 3, Step 13: Share notebook entries  
Inv. 2, Part 4, Step 6: Discuss the video with the class  
Inv. 2, Part 4, Step 12: Have a sense-making discussion  
Inv. 3, Part 3, Step 7: Discuss the video  
Inv. 3, Part 3, Step 13: Answer the focus question  
Inv. 3, Part 4, Step 5: Discuss rapid changes |
| Some systems appear stable, but over long periods of time will eventually change. | Inv. 2, Part 1, Step 7: Guide the analysis of data  
Inv. 2, Part 2, Step 16: Discuss erosion, deposition, and soils  
Inv. 2, Part 3, Step 9: Have a sense-making discussion  
Inv. 2, Part 3, Step 12: View online activity  
Inv. 2, Part 3, Step 13: Share notebook entries  
Inv. 3, Part 3, Step 7: Discuss the video  
Inv. 3, Part 3, Step 13: Answer the focus question  
Inv. 3, Part 4, Step 5: Discuss rapid changes |
## Crosscutting Concepts

### Grades 3–5 Crosscutting Concept Statements

<table>
<thead>
<tr>
<th>Energy Module</th>
<th>Environments Module</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inv. 2, Part 3, Step 17: Have a sense-making discussion</td>
</tr>
</tbody>
</table>

Some systems appear stable, but over long periods of time will eventually change.

Inv. 2, Part 1, Step 7: Guide the analysis of data
Inv. 2, Part 2, Step 16: Discuss erosion, deposition, and soils
Inv. 2, Part 3, Step 9: Have a sense-making discussion
Inv. 2, Part 3, Step 12: View online activity
Inv. 2, Part 3, Step 13: Share notebook entries
Inv. 2, Part 4, Step 6: Discuss the video with the class
Inv. 2, Part 4, Step 12: Have a sense-making discussion
Inv. 3, Part 3, Step 7: Discuss the video
Inv. 3, Part 3, Step 13: Answer the focus question
Inv. 3, Part 4, Step 5: Discuss rapid changes

Change is measured in terms of differences over time and may occur at different rates.

Inv. 2, Part 1, Step 7: Guide the analysis of data
Inv. 2, Part 2, Step 16: Discuss erosion, deposition, and soils
Inv. 2, Part 3, Step 9: Have a sense-making discussion
Inv. 2, Part 3, Step 12: View online activity
Inv. 2, Part 3, Step 13: Share notebook entries
Inv. 3, Part 3, Step 7: Discuss the video
Inv. 3, Part 3, Step 13: Answer the focus question
Inv. 3, Part 4, Step 5: Discuss rapid changes

Crosscutting Concepts Opportunities in FOSS
REFERENCES


