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 bridges—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 2 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 second 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.
Crosscutting Concepts—Grade 2

For second grade, we recommend focusing on the crosscutting concepts of patterns, cause and effect, energy and matter, stability and change, and structure and function, 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 second 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 to the left). These Grade-Level Examples, shown in the table below for grade two and discussed in this chapter, can bridge between FOSS modules (instructional segments).

<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
<th>Pebbles, Sand, and Silt Module</th>
<th>Solids and Liquids Module</th>
<th>Insects and Plants Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause and effect</td>
<td>Inv 4, Part 4, Step 3: Have a sense-making discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale, proportion and quantity</td>
<td></td>
<td>Inv 2, Part 3, Step 9: Have a sense-making discussion</td>
<td></td>
</tr>
<tr>
<td>Energy and matter</td>
<td>Inv 4, Part 4, Step 8: Have a sense-making discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure and function</td>
<td></td>
<td></td>
<td>Inv 3, Part 3, Step 3: Introduce proboscis</td>
</tr>
<tr>
<td>Stability and change</td>
<td>Inv 1, Part 1, Step 9: Introduce weathering and sand</td>
<td>Inv 4, Part 1, Step 25: Have a sense-making discussion</td>
<td></td>
</tr>
</tbody>
</table>

Grade-level examples for crosscutting concepts described in this chapter.
Introduction

The crosscutting-concept dimension of the NGSS will take time to integrate into your practice. Students will 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.
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 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 K–2, children recognize that patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence (Next Generation Science Standards, Appendix G, 2013, page 82).

Introducing patterns. Second-grade students previously have had some guided experience in working with patterns. They will still need guidance and support on when to look for 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, 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? Did they all have the same texture? Color? Shape?

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.

➤ What do you see? Do 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 try to figure out why those patterns happen, and we can use patterns to help explain what (the phenomena) we are studying.

General strategies for patterns.

• Start with focusing students on two objects, such as two bottles of liquids. 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 fits the pattern.

• Use a graphic organizer as a class to identify and record similarities and differences to explore a pattern. (See the example from the Solids and Liquids Module in the sidebar).

• Once students are able to determine a pattern, ask students to develop a ‘rule’ about the pattern of the objects. 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.

• This pattern is similar to ________.

Taking it further.

• Create an ongoing list of patterns. Have students generate the headers for these lists, such as, Natural (all rocks are ________) or Tested (Heavy, rigid objects are good bases for towers).

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

A graphic organizer can be used to help students describe what properties are the same and different about liquids and solid particles.
**Grade-level examples.** In the *Insects and Plants Module*, Investigation 3, Part 3, students observe the changes in milkweed bugs over several weeks. The teacher introduces the names of the stages in the life cycles of milkweed bugs, such as the eggs and nymphs. When the milkweed bugs are adults, students observe a cluster of eggs that look very similar to the eggs they observed before they hatched. Students are asked to describe the pattern and consider what might occur with these new eggs. The life-cycle of milkweed bugs is a pattern. As students progress in their abilities to recognize patterns, students can compare the patterns, life cycles of milkweed bugs and mealworms, to determine if all insects’ life cycles are the same.

Later in the *Insects and Plants Module*, Investigation 5, Part 3, students read an article in *Science Resources*. They learn about the life cycles of many different organisms. As students learn about more organisms and their life cycles, students can compare those patterns to previous ones in order to make predictions.

**Connections between modules.** The purpose of sharing these connections is for teachers to bridge investigations and modules using a particular crosscutting concept. Once students have started using a crosscutting concept in one context, connections can be made to new experiences with that concept. As students’ use of patterns increases, see if they can identify opportunities to look for patterns or even look for them without being asked to do so.

In the *Pebbles, Sand, and Silt Module*, students observe a mixture of rocks, gravel, and sand. They are asked to use screens to separate the mixture into the various sizes of earth materials. During the sense-making discussion, students consider if there is something about the size of the earth materials and the holes in the screen. They determine if the earth material is larger than the hole in the screen, they will stay on top. If they are smaller, they will pass through. In the *Solids and Liquids Module*, students observe the water level as they turn a bottle of water upside down. They determine the pattern that the water level is always flat and level. In the *Insects and Plants Module*, students compare life cycles of insects.

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 *Solids and Liquids Module* and are working in the *Pebbles, Sand, and Silt Module*, make a connection between the sorting of solid objects by their properties (patterns) and the sorting of rocks by their properties. Questions such as, “We noticed a pattern that some solids are flat. Is there a similar pattern for rocks? If we found another rock, do you think it would also have that property? 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 K–2, students learn that events have causes that generate observable patterns. They design simple tests to gather evidence to support or refute their own ideas about causes. (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, “Pieces of rocks go through some screens but not others. Sometimes, the rocks don’t go through the screen.” You observed that happen. In science, we call those effects. Rocks moving through the screen is one effect. We can think about what caused the rocks to go through the screen. When we figure out what made them go through (effect), we know the cause.

What causes some rocks to go through the screen and others to stay on top?
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 some items melt in a hot water bath, others will not. Other times, students manipulate the cause and observe the effect, such as what happens (the effect) when I rub two rocks together.

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 ______ .

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 when you turn a bottle of water upside down, the water always stays level with the ground.

Grade-level examples. In the *Pebbles, Sand, and Silt Module*, Investigation 4, Part 4, students consider how rocks move after reading an article about erosion. They compare different designs to solve the problem of soil erosion. Students use their understanding of how rocks break into smaller pieces and are moved by wind and water to compare how well the designs might prevent erosion. This is a good opportunity to introduce the sentence frame “I think *<design feature or cause>* will *<predicted effect>*.”

In the *Insects and Plants Module*, students observe the germination of plants in some planting conditions, but not others. Students record their observations using a notebook sheet. Students at the beginning of second grade will likely need guidance to determine which of environmental conditions (water, light, or temperature) is necessary for germination. Questions such as, “Let’s look at the amount of light that..."
was used when the plants grew. Did the plants grow in light, dark, or both? Did the plant grow when there was water or no water? What does this tell us about what is needed for germination?” Questions can be asked to have students communicate the cause-and-effect relationships. To take the crosscutting concept a bit further, students can ask cause-and-effect questions, such as “What would happen if we _____?” or suggest patterns that could be tested.

**Connections between modules.** In the Insect and Plants Module, students observe the effects of water and light on brassica plants. In the Solids and Liquids Module, students examine the cause-and-effect relationships of solids in water. In the Pebbles, Sand, and Silt Module, students examine the effects of rubbing rocks together.

When beginning to look at cause-and-effect relationships in a second or third module, make connections to those relationships established in the first. For example, when looking at the cause-and-effect relationships for solids in water, ask students to recall the relationships from the Pebbles, Sand, and Silt Module. How could they use what they learned about the effects of rubbing rocks together to find out more about solids and liquids? When they looked at the effects of rubbing rocks together, they had to compare the rocks before and after rubbing. To see what water does to solids, they have to observe the solids closely before and after adding water.
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. In second grade, using comparing words, such as faster and slower, are a first step towards understanding scale, proportion, and quantity.

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 K–2, students use relative scales (e.g., bigger and smaller, hotter and colder, faster and slower) to describe objects. They use standard units to measure length. (Next Generation Science Standards, Appendix G, 2013, page 84).

Introducing scale, proportion, and quantity. In grades K–2, 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 scale. For example, when students describe that one rock is bigger than another, you might say,

Many of you observed that the dark gray rock is larger than the white rock. Scientists compare objects like rocks. They might say one rock is larger than another rock. They also use words like smaller and wider to compare rocks. How do you know if one rock is larger than another rock?

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 height of plants, they could identify them from shortest to tallest. As they learn to measure distance or length, those can be added to their observations.
- Start a list of comparing words students use when they describe objects or organisms. When students record observations in their notebooks, remind them of comparing words they can use.
- Help students improve their drawings by having them critique illustrations you make, such as a plant being very small compared to a cup. 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.**

- This <object> is <comparing word> than this <object>.
- If I compare the (size, speed, temperature, etc.), the ______.
- The amount of ______ is ______ than the amount of ______.

**Taking it further.**

- Ask students to find objects that are taller, shorter, heavier, lighter, etc. than an object they are observing. For example, when they are observing a snail, ask them to find a snail that is faster or slower.
- Discuss why scale is important for scientists and engineers. For example, when scientist study trees, if they know a tree is getting taller, it is growing.

**Grade-level examples.** In the Solids and Liquids Module, Investigation 2, Part 3, students observe water in various containers of different sizes and shapes and then observe how water moves in a bottle as it is turned upside down. During a sense-making discussion, students can discuss their observations of the liquid level in a wide container compared to a narrow container. When they observe the liquid level in a turning bottle, students can be asked questions such as, “When you started, all of the water was at the bottom of the bottle, when the bottle is upside down, where is most of the water? Later in Investigation 3, Part 1, students are introduced to solids of different sizes, such as cornmeal and rice. Students observe the solids are small pieces called particles. These solids can then be compared based on their particle size.

**Connections between modules.** In the Pebbles, Sand, and Silt Module, students observe rocks of different sizes throughout the module. They compare the sizes of boulders, cobbles, pebbles, gravel, sand, silt and clay. In the Solids and Liquids Module, students compare the particle sizes of solids. Throughout these modules, students are making comparisons between objects. Students should be using comparing words throughout second grade. As the year progresses, linear measurements should be used as evidence of objects being larger or smaller. In later grades, other quantitative data can be used for comparisons.
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 parts of a system and how that system works can be considered starting in second grade.

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 K–2, students understand objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together. (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 plant. 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 plant 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.

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 do the roots do for the plant?

Continue asking students to identify the various parts of the plant. Ask students what might happen if the plant didn’t have any roots. Identify that all the parts of the plant work together to help the plant live.

General strategies for systems and system models.

• Start with focusing students on a scientific illustration of a system and identifying the parts. Have students share their observations during a discussion. Draw the system they are studying in the class notebook. Hand a student a word card identifying one of
the parts of the system and have them tape the word card next to the corresponding part in the drawing. Repeat this with the remaining parts of the system.

• Make a poster 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 base of a tower.

**Sentence frames for systems and system models.**

• The parts of the system are ______.

• <One part> works with <second part> by ______.

**Taking it further.**

• Do a think aloud to model how to identify more complex systems. Begin at the bottom of the system and identify the parts as you move up the system rather than going in a random order. Another technique is to work from the largest part of the system towards the smallest.

• Provide a drawing starter in the class notebook by drawing the largest part of the system, such as the footpath of a bridge. Have several students add additional parts of the system to the drawing.

• Discuss why scientists and engineers study systems. Ask students how focusing on a system helps them understand more about the object or organism.
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. Younger students begin to consider the matter of objects they directly experience.

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 K–2, students observe objects may break into smaller pieces, be put together into larger pieces, or change shapes. (Next Generation Science Standards, Appendix G, 2013, page 86).

Introducing energy and matter. Start with an object students have worked with where the object can be broken into smaller pieces or smaller pieces can make a larger object, such as a brick. After assembling the brick, draw the original pieces of clay soil in the class notebook. Ask students to identify the pieces they see and have a student draw the clay after making the brick. This should include a smaller piece of dry grass or straw. Introduce matter.

Scientists call objects like bricks matter. Everything you see in this room is made of matter. There are different types of matter you will learn about as you get older. The matter we started with was pieces of clay soil.
When we added water and the grass and left it to dry, we made bricks. Bricks are made of smaller pieces. The clay soil and grass are still there, they just looks different now. Scientists and engineers study what happens to matter when they do things to it, like add other matter to it.

In second grade, focus on objects that can be broken up into smaller pieces or are made of smaller pieces. In later grades, students will consider how matter moves in greater depth.

**General strategies for energy and matter.**

- Asking questions to focus students attention on what the object (matter) looks like at a particular time can aid in developing this concept. For example,
  - What does the clay soil and grass look like at the start? What happens to the object next? What does the object look like at the end?

- Visually represent the changes to the object’s energy using arrows or a series of drawings.

- Provide a series of images that show an object changing in an incorrect order, have students identify the correct order.

**Sentence frames for energy and matter.**

- The object starts ______ . Next, the object ______.

- The object changes when ______.

- To change the object, I ______.

**Taking it further.**

- Discuss why scientists and engineers study how an object changes.

**Grade-level example.** In the Solids and Liquids Module, Investigation 4, Part 4, students investigate the properties of solids when heated and cooled. Students observe the properties of ice, margarine, and chocolate as solids and then liquids. They describe their observations when heat (energy) is added and later when heat (energy) is removed. Students can think about the matter as it changes. “What does it look like at the beginning? Is there more or less chocolate now that it melted?” are questions students can grapple with. This is a good opportunity to introduce the sentence frame, “To change the properties of ice, I ______.” This serves as a claim that students can support with data. The idea of objects being broken into smaller pieces and smaller pieces can make larger objects serve as a foundation for work in later grades.
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 K–2, students observe the shape and stability of structures of natural and designed objects and how they are related to their function(s) (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 designing a tower using solids. I want you to look at the parts of the tower. Scientists call the parts of objects and organisms, like the base, structures. Structures have properties.*

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

➤ What do you notice about the base of your tower? What shape is it? What properties do the objects at the base have? Why do you think the objects at the base need those properties?
When scientists and engineers look at structures, they often try to figure out what the structure 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. The structure is the base, the function is to support the weight of the tower.

**General strategies for structure and function.**

- Start with some examples of functions of common objects in the classroom. For example,
  - *What are the structures or parts of your shoe?*
- Once students have identified the structure (object or component), ask what one structure does. For example,
  - *What job or function does the shoelace do?*
- Ask students to identify the functions of a designed object, such as a bicycle. What structures are important to make the object work? What shapes or properties do those structures need to have?

**Sentence frames for structure and function.**

- One structure of this object is _____.
- The shapes I see are _____.
- The properties of that structure are _____.
- The function is _____.

**Taking it further.**

- Ask students to identify an important structure of what they are observing, such as the segments of mealworms. Have them identify the function of the segments. Ask students to consider that would happen if the structure was made out of something different or wasn’t present. If the function of the segments is to help the organism move in different directions, what would happen if the organism didn’t have any segments?
- As students progress, have them label the structures of an object drawn in the class notebook in one color and use a second color to identify the function of those structures.

**Grade-level example.** In the *Insects and Plants Module*, Investigation 3, Part 3, students observe the structures of a milkweed bug. They identify the proboscis, legs, head, thorax, and abdomen and determine the function of the proboscis. Students can consider why the proboscis needs to be long and thin. If students are up for the challenge, they can discuss the function other structures, such as why it is important that the legs are able to bend.
Later in Part 4 of the same investigation, students are given a design challenge to make a model of a habitat for an insect to survive. While this is different than looking at the structures and functions of an insect or bridge, students can think about their design in a similar way. For example, students know the insect will need food, so the habitat needs to be structured in a way that provides food. If the insect is unable to climb, the food will need to be down low in the habitat. In second grade, the idea of structure and function is strongly connected with systems and system models. The parts of the insect habitat can also be analyzed as a system that works together to meet the needs of the insects.

**Connections between modules.** In the **Solids and Liquids Module**, students construct towers and bridges and can look at the function of parts and the properties of the structures, such as rigid or flexible. In the **Insects and Plants Module**, students compare the structures of different insects. As students are able to identify structures and functions, ask them to make comparisons between structures, for example, “When we observed the silkworm cocoon, you said the cocoon needs to be rigid to protect the insect inside. Now you have made a bridge, why does part of the bridge need to be rigid? Is that the same as why the cocoon needs to be rigid?”
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 K–2, students observe some things stay the same while other things change, and things may change slowly or rapidly (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 students 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 bridge structure moves when you touch it, but the tower doesn’t fall down.

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.]

NOTE

Stability and change is a focus for second grade.
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 Pebbles, Sand, and Silt Module, students look at changes when they rub rocks together. Ask questions that help them to discover the changes. Students might notice the small pieces of rocks that have come completely off and the rocks are smaller now. Also focus students’ attention to what has remained the same, such as the patterns in the rock. Going even further, students are asked to consider how rocks might rub together in nature and how long that change would take.

In the Solids and Liquids Module, students look at changes when solids are mixed with water. In this investigation, some of the solids change drastically while others change very subtly. Additionally, when the water dries, students observe the changes again. In this example, students can compare the original solid with the solid and water and
then again with the solid after the water evaporates. This provides a level of support for students as changes, or lack of changes, are easier to determine when compared to the starting solid.

**Connections between modules.** In the **Pebbles, Sand, and Silt Module**, students look at images of designs to minimize erosion. They discuss how humans can construct ways to prevent changes. In the **Solids and Liquids Module**, students mix liquids with water and observe changes before and after shaking. In the **Insects and Plants Module** students look at the change in various insects as they progress through different stages. Students can compare the time those changes take to occur and specific changes, such as, the milkweed bugs’ and butterflies’ life cycle. As students progress through the modules, revisit previous changes and the strategies used to observe and record those changes. Ask students how they can replicate those strategies in a new context.
CROSSCUTTING-CONCEPT QUESTIONS

This table contains sample crosscutting-concept questions that can be incorporated into a sense-making discussion for K–8. For questions that connect with science and engineering practices as well, the connection appears in parentheses.

<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></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></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></td>
<td></td>
</tr>
<tr>
<td>• What is causing the pattern? What does the pattern tell me about (the system or phenomenon)? (Designing solutions)</td>
<td></td>
<td></td>
</tr>
<tr>
<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>
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</tr>
<tr>
<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>
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<td></td>
</tr>
</tbody>
</table>

### Crosscutting-Concept Questions

**Systems and system models**
- What is the function of the system?
- What are the parts or components of the system? (Developing and using models)
- What is the role <job, function> of each part? How does <one part> work with <another part>?
- How can we develop a model of this system? What is not part of the system? What happens to the system when ______ is removed?
- What system or systems do we need to model in order to explain this phenomenon? (Developing and using models)

**Energy and matter**
- What matter is part of this system?
- What matter comes into the system?
- What matter moves or changes in the system?
- What matter goes out of the system?
- What does energy do in the system?
- How is energy moving in the system?
- How does energy enter the system?
- How does energy leave the system?
- What matter flows into, out of, and within the system? What physical and chemical changes occur during this phenomenon? (Developing and using models)
- What energy transfers occur into, out of, or within the system? What transformations of energy are important to its operation? (Developing and using models)
- What inputs are needed for the system to function? What are the desired outputs of the system? (Defining problems)

**Structure and function**
- What particular shapes or structures are observed in this system at this scale? (Planning and carrying out investigations)
- What roles do these structures play in the functioning of the system? (Developing and using models)
- What design features of appearance and structure are important? (Defining problems)
- What properties of the components are important for the function of this design? (Designing solutions)

**Stability and change**
- What changes do I notice? How quickly is the change happening? (Analyzing and interpreting data)
- What can I investigate more closely to recognize the cause of a change? (Planning and carrying out investigations)
- What changes would cause it to become unstable or to fail? (Developing and using models)
- How can I improve the stability of my design? (Designing solutions)
## Crosscutting Concepts—Grade 2

### 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 K-2 Crosscutting Concept Statements*</th>
<th>Pebbles, Sand, and Silt Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns</td>
<td>Inv 1, Part 9: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv 1, Part 10: Assess progress: performance assessment</td>
</tr>
<tr>
<td></td>
<td>Inv 2, Part 13: Assess progress: performance assessment</td>
</tr>
<tr>
<td>Events have causes that generate observable patterns; simple tests can be designed to gather evidence to support or refute student ideas about causes.</td>
<td>Inv 1, Part 15: Review the three volcanic rocks</td>
</tr>
<tr>
<td></td>
<td>Inv 2, Part 15: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv 2, Part 9: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv 2, Part 12: Share notebook entries</td>
</tr>
<tr>
<td></td>
<td>Inv 3, Part 14: Assess progress: notebook entry</td>
</tr>
<tr>
<td></td>
<td>Inv 3, Part 12: Share sand sculptures</td>
</tr>
<tr>
<td></td>
<td>Inv 4, Part 9: Assess progress: performance assessment</td>
</tr>
<tr>
<td></td>
<td>Inv 4, Part 8: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv 4, Part 25: Discuss the reading</td>
</tr>
</tbody>
</table>

*From Next Generation Science Standards, Volume 2, Appendixes, pages 92-95
### Solids and Liquids Module

- Inv 1, Part 3, Step 7: Assess progress: performance assessment
- Inv 2, Part 1, Step 7: Assess progress: performance assessment
- Inv 2, Part 3, Step 20: Share notebook entries
- Inv 3, Part 3, Step 7: Assess progress: performance assessment
- Inv 3, Part 4, Step 7: Assess progress: notebook entry

### Insects and Plants Module

- Inv 1, Part 3, Step 9: Answer the focus question
- Inv 2, Part 2, Step 6: Assess progress: performance assessment
- Inv 2, Part 3, Step 14: Share notebook entries
- Inv 2, Part 4, Step 14: Share findings
- **Inv 3, Part 3, Step 6: Observe reproduction**
- Inv 4, Part 2, Step 16: Have a sense-making discussion
- Inv 4, Part 3, Step 6: Focus question: What is the life cycle of the silkworm?
- Inv 4, Part 4, Step 9: Assess progress: performance assessment
- Inv 5, Part 1, Step 8: Assess progress: performance assessment
- Inv 5, Part 3, Step 11: Assess progress: notebook entry
- Inv 5, Part 3, Step 14: View video: Insect
- **Inv 5, Part 3, Step 18: Have a sense-making discussion**

## Crosscutting Concepts Opportunities in FOSS

1. **Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.**
   - Inv 1, Part 1, Step 9: Have a sense-making discussion
   - Inv 1, Part 3, Step 9: Answer the focus question
   - Inv 2, Part 1, Step 10: Assess progress: performance assessment
   - Inv 2, Part 3, Step 14: Share notebook entries
   - Inv 3, Part 3, Step 7: Assess progress: performance assessment

2. **Events have causes that generate observable patterns; simple tests can be designed to gather evidence to support or refute student ideas about causes.**
   - Inv 1, Part 2, Step 15: Review the three volcanic rocks
   - Inv 2, Part 1, Step 15: Have a sense-making discussion
   - Inv 2, Part 2, Step 9: Have a sense-making discussion
   - Inv 2, Part 2, Step 12: Share notebook entries
   - Inv 3, Part 2, Step 14: Assess progress: notebook entry
   - Inv 3, Part 3, Step 12: Share sand sculptures

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# Crosscutting Concepts—Grade 2

<table>
<thead>
<tr>
<th>Grades K-2 Crosscutting Concept Statements*</th>
<th>Pebbles, Sand, and Silt Module</th>
</tr>
</thead>
</table>
| Relative scales allow objects and events to be compared and described (bigger and smaller; hotter and colder; faster and slower). | Inv 2, Part 1, Step 13: Assess progress: performance assessment  
Inv 2, Part 1, Step 13: Introduce silt  
Inv 3, Part 3, Step 9: Set sculptures to dry  
Inv 4, Part 4, Step 5: Read “Ways to Represent Land and Water” |
| Systems in the natural and designed world have parts that work together. | |
| Objects may break into smaller pieces, be put together into larger pieces, or change shapes. | Inv 3, Part 5, Step 10: Use the bricks  
Inv 3, Part 5, Step 14: Revisit the guiding question |
### Solids and Liquids Module

- Inv 2, Part 3, Step 9: Have a sense-making discussion
- Inv 3, Part 1, Step 13: Introduce particle
- Inv 3, Part 2, Step 8: Assess progress: performance assessment
- Inv 4, Part 4, Step 15: Review towers

### Insects and Plants Module

- Inv 4, Part 4, Step 8: Have a sense-making discussion
<table>
<thead>
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<th>Grades K-2 Crosscutting Concept Statements*</th>
<th>Pebbles, Sand, and Silt Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>The shape and stability of structures of natural and designed objects are related to their function(s).</td>
<td>Inv 1, Part 9: Introduce weathering and sand</td>
</tr>
<tr>
<td>Some things stay the same while other things change. Things may change slowly or rapidly.</td>
<td>Inv 1, Part 8: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv 1, Part 15: Review the three volcanic rocks</td>
</tr>
<tr>
<td></td>
<td>Inv 2, Part 9: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv 2, Part 28: Conduct the demonstration live (optional)</td>
</tr>
<tr>
<td></td>
<td>Inv 4, Part 26: Share notebook entries</td>
</tr>
<tr>
<td></td>
<td>Inv 4, Part 4: Answer the focus question</td>
</tr>
</tbody>
</table>
### Solids and Liquids Module
- Inv 1, Part 1, Step 10: Develop vocabulary
- Inv 1, Part 2, Step 15: Have a sense-making discussion
- Inv 1, Part 3, Step 14: Share notebook entries
- Inv 1, Part 4, Step 8: Assess progress: performance assessment
- Inv 1, Part 4, Step 11: Have a sense-making discussion
- Inv 1, Part 4, Step 18: Compare bridges and towers
- Inv 1, Part 4, Step 24: View the video

### Insects and Plants Module
- Inv 1, Part 1, Step 6: Discuss structure and function
- Inv 1, Part 2, Step 2: Discuss structures and behaviors
- Inv 1, Part 2, Step 5: Assess progress: performance assessment
- Inv 1, Part 2, Step 16: Draw beetle body parts and structures
- Inv 1, Part 2, Step 25: Share notebook entries
- Inv 2, Part 3, Step 3: Harvest the seeds
- Inv 2, Part 3, Step 14: Share notebook entries
- **Inv 3, Part 3, Step 3:** Introduce *proboscis*
- Inv 3, Part 3, Step 10: Review vocabulary
- **Inv 3, Part 4, Step 13:** Introduce the design challenge
- Inv 5, Part 1, Step 16: Share notebook entries
- Inv 5, Part 4, Step 8: Assess progress: performance assessment
- Inv 5, Part 4, Step 15: Have a sense-making discussion

### Crosscutting Concepts
- Some things stay the same while other things change. Things may change slowly or rapidly.
- Inv 1, Part 1, Step 9: Introduce weathering and sand
- Inv 1, Part 2, Step 8: Have a sense-making discussion
- Inv 1, Part 2, Step 15: Review the three volcanic rocks
- Inv 2, Part 2, Step 9: Have a sense-making discussion
- Inv 2, Part 4, Step 28: Conduct the demonstration live (optional)
- Inv 4, Part 1, Step 26: Share notebook entries
- Inv 4, Part 4, Step 4: Answer the focus question
- Inv 4, Part 1, Step 12: Discuss change
- **Inv 4, Part 1, Step 25:** Have a sense-making discussion
- Inv 4, Part 2, Step 11: Observe the bottles after settling
- Inv 4, Part 4, Step 21: Discuss the reading
- Inv 4, Part 4, Step 23: Discuss the reading
- Inv 3, Part 2, Step 1: Observe the vials
- Inv 3, Part 3, Step 9: Have a sense-making discussion
- Inv 3, Science Extension: Start a milkweed bug time line
- Inv 4, Part 1, Step 9: Focus question: What do silkworms need to live?
- Inv 4, Part 2, Step 7: Observe growing larvae
- Inv 4, Part 3, Step 8: Make life-cycle chart entries
- Inv 5, Part 1, Step 11: Watch for molting
REFERENCES


