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 1 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 first 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 1_
For first grade, we recommend focusing on the crosscutting concepts of patterns, cause and effect, 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 first 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).

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Grade-level examples for crosscutting concepts described in this chapter.
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 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 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. First-grade students previously have had some guided experience in working with patterns. They will still need significant 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 or interactions, such as blowing air on the cotton ball and on the plastic-foam ball. Ask them to compare the two. Add a third, such as the feather, ask what is the same or different with all three of these. If students determine the objects or interactions 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 Air and Weather 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 lists of patterns. Have students generate the headers for these lists, such as, Natural (Plants need water) or Tested (Shiny and smooth surfaces reflect light).
• 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.

**Grade-level examples.** In the *Air and Weather Module*, Investigation 2, Part 4, students observe the changes in the Moon over several weeks. The teacher guides students to record these observations on a Moon calendar. When the Moon gets back to the shape they observed on the first day, students have a discussion looking for patterns. Students are asked to describe the pattern for four weeks. To make this more manageable, the smaller changes are discussed first, for example, they notice the Moon getting bigger until it is full. The appearance of the Moon over four weeks is a pattern.

Later in the *Air and Weather Module*, Investigation 4, Part 2, students look at data about the number of daylight hours in each month. The data are organized and displayed. They look for increasing and decreasing patterns in the data. They identify the summer months that have more daylight compared to winter months and use the data to make predictions.

In the *Sound and Light Module*, Investigation 3, Part 2, students look at an image of a tree and its shadow and a diagram of the tree, shadow, and Sun. They compare the two and determine the Sun is always on the opposite side of the object than the shadow. This is a pattern that students can test with their flashlight and objects in the room during the next part.

In the *Plants and Animals Module*, Investigation 4, Part 2, students compare new plants to parent plants and discuss the similarities and differences. They determine that both plants have many of the same structures, but they might vary in size, shape, color, and quantity. This is a very important pattern with living organisms, offspring tend to have the same structures as their parents.

**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 these three module 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 *Air and Weather Module* and are working in the
Plants and Animals Module, make a connection between the light source always being on the opposite side of the shadow (patterns) and what is always true about new plants and parent plants. Questions such as, “We noticed a pattern that shadows are always on the opposite side from the light source. Is there a similar pattern or something that is always true about new plants and parent plants? If we found another new plant, do you think it would also have the same structures? 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, population 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, “You could make some objects roll across the table when you blow on them with the straw. Sometimes, the objects don’t move very far.” You observed that happen. In science, we call those effects. Objects rolling across the table is one effect. We can think about what caused the objects to move. When we figure out what made them move (effect), we know the cause.

➤ What causes some objects to move across the table and not others?

**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 cuttings will grow and others will not. Other times, students manipulate the cause and observe the effect, such as what happens (the effect) when I pump up the balloon even more.

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 have a longer tube, the pitch is lower.

Grade-level examples. In the Air and Weather Module, Investigation 1, Part 3, students consider what happens when air is pushed into a smaller space. They work with one syringe and find they can’t push the plunger all the way down if they close the end. Students use their understanding of air taking up space to then connect a second syringe and push and pull the other plunger.

Later in the Air and Weather Module, Investigation 3, Part 3, observe the wind and the motion of a pinwheel. During the sense-making discussion, students consider what causes the pinwheel to turn at different speeds. This is a good time to use the sentence frame, “I think ______ is causing ______ .”

In the Sound and Light Module, Investigation 1, Part 1, observe a table fiddle made of string. The string is plucked and students make observations of what they can see and hear. The students identify what the effect of plucking the string is and what cause the string to make a sound. While this seems pretty straightforward, understanding cause-and-effect relationships strengthens their understanding and enables them to make predictions in the future.
Later in Investigation 4, Part 1 of the Sound and Light Module, work with redirecting light using mirrors. This presents an opportunity to look at both cause-and-effect and effect-and-cause. Questions such as, “What caused the light to shine on the ceiling?” and “What do you need to do (cause) so the light shines on the book (effect).

In the Plants and Animals Module, Investigation 1, Part 1, students plant seeds and work with the simple, yet important, relationship of water causing the germination of seeds. 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.** 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 relationship between plucking the string and sound, ask students to recall the wind and pinwheel relationship from the Air and Weather Module. How could they use what they learned about the effects of wind on the pinwheel to find out more about sound? When they looked at the effects of wind, they had to compare the pinwheel in windy and calm conditions. To see what plucking the string with different intensity does to the sound, they have to observe the sound with a regular, gentle, and hard pluck.
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 first 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 wheat roots are longer than the leaves. Scientists compare objects like plants. They might say the roots are longer or shorter than something else. They also use words like smaller and wider to compare other things. How do you know if the roots are longer than the leaves?

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 order 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 parent plant, ask them to find a plant that has smaller leaves or more roots.
• Discuss why scale is important for scientists and engineers. For example, when scientist study trees, if they know a plant is getting taller, it is growing.

**Connections between modules.** Throughout these modules, students are making comparisons between objects. Students should be using comparing words throughout first grade. As the year progresses and students develop strategies for more accurately comparing two objects, incorporate these into instruction. 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 first 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 the syringe system in the Air and Weather Module. 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 syringe 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 plungers do for the system?

Continue asking students to identify the various parts of the system. Ask students what might happen if the syringe didn’t have one of the plungers. Identify that all the parts of the system work together to help the system work.

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 students word cards identifying parts of the system and have them tape the word card next to the corresponding part in the drawing.
• 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 cup in a spoon-gong system.

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

• The parts of the system are ______.

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

**Grade-level examples.** In the Sound and Light Module, Investigation 2, Part 3, students are introduced to the spoon-gong system and identify the parts and how the parts work together. The system is analyzed and students develop a model on how sound travels from one part of the system to another.

Later in Investigation 4, Part 4, of the Sound and Light Module, describe and manipulate a flashlight, mirror, and book system. The Investigations Guide provides a series of questions to help students think about the path light travels through their system.

In the Plants and Animals Module, students observe a terrarium system and identify how the terrarium is setup with plants and animals. Students predict what changes might occur during the next few weeks.

**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 string connecting two cups in a string-telephone system. 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.

**Connections between modules.** In these examples, students define the parts of the system and how they work together. As students work with the first module, have them record their system in their notebooks. When working with the second system, have students revisit the first system and discuss how they drew it in their notebook. Ask them if they could use a similar strategy for recording the new system.
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).

This crosscutting concept is not addressed in first grade and developed to a small degree in grades K and 2. Strategies are shared and can be used when the opportunity presents itself.

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 object look like at the start? What happens to the object next? What does the object look like at the end?
Crosscutting Concepts—Grade 1

- Visually represent the changes to the matter of an object using arrows or a series of drawings.
- Provide a series of images that show an object changing in a 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’s matter changes.
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 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 observing alfalfa and grass for a little bit. I want you to look at the parts of the plants. Scientists call the parts of objects and organisms, like the roots, structures. Structures have properties.

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

➤ What do you notice about the roots? What shape are they? What properties do the roots have? Why do you think the roots need those properties?

NOTE
Structure and function is a focus for first grade.
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 root, the function is to take up water.

**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 napkins on parachutes. Have them identify the function of the napkin. 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 napkin is to capture the air, what would happen if the parachute didn’t have the napkin?
- As students progress, have them label the structures of an object drawn in the class notebook in one color and use a different color to identify the function of those structures.
Grade-level example. In the Plants and Animals Module, Investigation 1, Part 2, students reflect on their initial observation of plants growing in planters they set up a week before. Students are asked to call out the plant parts they observed or know about, which are identified as structures. You can then introduce the idea that plants have structures that perform activities that are important to the survival of the plants and the activities performed by those structures are identified as functions. From this introduction, forward properties of organisms are consistently identified as structures, and students are continually asked to analyze the structures in terms of the functions they perform to ensure the continued survival of organism. Structure and function becomes a lens that students use continually to observe their universe.

Connections between modules. In the Air and Weather Module, students construct kites and can look at the function of parts and the properties of the structures, such as rigid or flexible. In the Plants and Animals Module, students compare the structures of different plants. As students are able to identify structures and functions, ask them to make comparisons between structures, for example, “When we observed the kite, you said the tail needs to be light and long. Now you are looking at plants, why does the stem need to be strong?”

NOTE
In the Investigations Guide, you are directed to this Crosscutting Concepts—Grade 1 chapter for information on how to engage students with the concept of structure and function.
Crosscutting Concepts—Grade 1

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 structure moves when you touch it, but that it 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.]
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 Air and Weather Module, students look at changes of the position of the Sun’s shadow at different times of the day. Students record the time of sunrise and sunset over the week as well. Ask questions that help them to discover the changes. Students might notice that the time of the sunrise is getting earlier and earlier from winter to summer and that the sunset is getting later. Focus students’ attention to what has remained the same, such as the pattern of the Sun moving across the sky.
## 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></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></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></td>
</tr>
<tr>
<td>• How can I show or represent these patterns in my model? (Developing and using models)</td>
<td>• What should we measure during our test? (Planning and carrying out investigations)</td>
<td></td>
</tr>
<tr>
<td>• What can I do to test these patterns? (Planning and carrying out investigations)</td>
<td>• What units should we use? (Planning and carrying out investigations)</td>
<td></td>
</tr>
<tr>
<td>• How can I record these patterns in my notebook? (Analyzing and interpreting data)</td>
<td>• What do we need to do to make these observations or measurements? (Planning and carrying out investigations)</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>• What relationships do you see in the measurements? (Analyzing and interpreting data)</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>
<td>• How can I use a model to test my design? (Designing solutions)</td>
<td></td>
</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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</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>
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</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>
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<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>
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<tr>
<td></td>
<td>- What inputs are needed for the system to function? What are the desired outputs of the system? (Defining problems)</td>
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</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.

### Grades K–2 Crosscutting Concept Statements *

Patterns in the natural and human-designed world can be observed, used to describe phenomena, and used as evidence.

Events have causes that generate observable patterns; simple tests can be designed to gather evidence to support or refute student ideas about causes.

### Air and Weather Module

- **Patterns**
  - Inv. 1, Part 1, Step 7: Explore objects
  - Inv. 1, Part 1, Step 15: Share notebook entries
  - Inv. 1, Part 2, Step 8: Have a sense-making discussion

- **Cause and effect: Mechanism and explanation**
  - Inv. 2, Part 2, Step 6: Assess progress: performance assessment
  - Inv. 2, Part 4, Step 14: Have a sense-making discussion
  - Inv. 2, Part 4, Step 19: Look for Moon patterns
  - Inv. 2, Part 4, Step 20: Describe Moon patterns
  - Inv. 3, Part 3, Step 12: Share notebook entries
  - Inv. 3, Part 4, Step 6: Introduce compass directions (optional)
  - Inv. 3, Part 4, Step 15: Share notebook entries
  - Inv. 4, Part 1, Step 5: Assess progress: performance assessment
  - Inv. 4, Part 1, Step 8: Focus question: What does the Moon look like at different times during a month?
  - Inv. 4, Part 2, Step 4: Look for patterns
  - Inv. 4, Part 3, Step 8: Focus question: How does the temperature and weather change over the seasons?

### *From Next Generation Science Standards, Volume 2, Appendixes, pages 92-95*
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<th>Sound and Light Module</th>
<th>Plants and Animals Module</th>
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<tr>
<td>Inv. 2, Part 2, Step 12: Answer the focus question</td>
<td>Inv. 1, Part 3, Step 14: Assess progress: performance assessment</td>
</tr>
<tr>
<td>Inv. 3, Part 1, Step 7: Introduce objects</td>
<td>Inv. 1, Part 3, Step 15: Make bar graphs after 1 week</td>
</tr>
<tr>
<td>Inv. 3, Part 1, Step 14: Assess progress: notebook entry</td>
<td>Inv. 1, Part 3, Step 16: Discuss wheat growth after 2 weeks</td>
</tr>
<tr>
<td><strong>Inv. 3, Part 2, Step 15: Use a reading comprehension strategy</strong></td>
<td>Inv. 1, Part 4, Step 10: Sort the leaves</td>
</tr>
<tr>
<td>Inv. 4, Part 1, Step 8: Introduce reflect</td>
<td>Inv. 1, Part 4, Step 11: Have a sense-making discussion</td>
</tr>
<tr>
<td>Inv. 4, Part 3, Step 15: Have a sense-making discussion</td>
<td>Inv. 2, Part 2, Step 18: Have a sense-making discussion</td>
</tr>
<tr>
<td><strong>Inv. 2, Part 2, Step 18: Have a sense-making discussion</strong></td>
<td><strong>Inv. 2, Part 3, Step 12: Observe growth over time</strong></td>
</tr>
<tr>
<td><strong>Inv. 4, Part 2, Step 21: Share notebook entries</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Inv. 1, Part 1, Step 7: Demonstrate the table fiddle</strong></td>
<td></td>
</tr>
<tr>
<td>Inv. 1, Part 1, Step 12: Introduce the book fiddle</td>
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<tr>
<td>Inv. 1, Part 2, Step 10: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Inv. 1, Part 2, Step 21: Use lid with salt and rice</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 1, Step 12: Answer the focus question</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 2, Step 13: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Inv. 2, Part 3, Step 17: Discuss the reading</td>
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</tr>
<tr>
<td>Inv. 3, Part 1, Step 7: Introduce objects</td>
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<tr>
<td>Inv. 3, Part 2, Step 8: Assess progress: performance assessment</td>
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<tr>
<td>Inv. 3, Part 3, Step 2: Demonstrate with wood</td>
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<tr>
<td>Inv. 3, Part 3, Step 3: Demonstrate with plastic</td>
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<tr>
<td>Inv. 3, Part 3, Step 4: Demonstrate with paper</td>
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</tr>
<tr>
<td>Inv. 4, Part 1, Step 6: Assess progress: performance assessment</td>
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</tr>
<tr>
<td><strong>Inv. 4, Part 1, Step 8: Introduce reflect</strong></td>
<td></td>
</tr>
<tr>
<td>Inv. 4, Part 1, Step 12: Assess progress: performance assessment</td>
<td></td>
</tr>
<tr>
<td>Inv. 4, Part 2, Step 17: Have a sense-making discussion</td>
<td></td>
</tr>
<tr>
<td>Inv. 4, Part 3, Step 10: Discuss observations</td>
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## Crosscutting Concepts—Grade 1

<table>
<thead>
<tr>
<th>Grades K–2 Crosscutting Concept Statements</th>
<th>Air and Weather Module</th>
</tr>
</thead>
</table>
| Events have causes that generate observable patterns. | Inv. 2, Part 2, Step 3: Practice measuring temperature  
Inv. 2, Part 2, Step 4: Predict the outdoor air temperature  
Inv. 2, Part 2, Step 20: Have a sense-making discussion  
Inv. 3, Part 1, Step 6: Assess progress: performance assessment  
Inv. 3, Part 3, Step 7: Assess progress: performance assessment  
**Inv. 3, Part 3, Step 8: Have a sense-making discussion**  
Inv. 3, Part 4, Step 7: Observe cloud movement |
| Relative scales allow objects and events to be compared and described. | Inv. 3, Part 2, Step 3: Introduce the wind scale |
| Systems in the natural and designed world have parts that work together. | **Inv. 1, Part 3, Step 10: Have a sense-making discussion**  
Inv. 1, Part 3, Step 11: Continue sense-making discussion  
Inv. 1, Part 4, Step 9: Compare syringe systems  
Inv. 1, Part 4, Step 19: Distribute the notebook sheet |
<p>| Objects and organisms can be described in terms of their parts. | |</p>
<table>
<thead>
<tr>
<th><strong>Sound and Light Module</strong></th>
<th><strong>Plants and Animals Module</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inv. 1, Part 1, Step 23: Assess progress: notebook entry</td>
</tr>
<tr>
<td></td>
<td><strong>Inv. 1, Part 1, Step 26: Have a sense-making discussion</strong></td>
</tr>
<tr>
<td></td>
<td>Inv. 1, Part 2, Step 13: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv. 1, Part 2, Step 14: Engage in argumentation (optional)</td>
</tr>
<tr>
<td></td>
<td>Inv. 1, Part 3, Step 16: Discuss wheat growth after 2 weeks</td>
</tr>
<tr>
<td></td>
<td>Inv. 2, Part 2, Step 18: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv. 4, Part 1, Step 12: Have a sense-making discussion</td>
</tr>
<tr>
<td></td>
<td>Inv. 4, Part 2, Step 17: Observe and discuss over time</td>
</tr>
</tbody>
</table>

|                           | Inv. 1, Part 3, Step 10: Have a sense-making discussion |
|                           | Inv. 1, Part 3, Step 11: Continue sense-making discussion |
|                           | Inv. 1, Part 4, Step 9: Compare syringe systems |
|                           | Inv. 1, Part 4, Step 19: Distribute the notebook sheet |
|                           | **Inv. 2, Part 2, Step 13: Assess progress: performance assessment** |
|                           | Inv. 2, Part 3, Step 2: Demonstrate the spoon-gong system |
|                           | Inv. 2, Part 3, Step 6: Focus question: How does sound travel from the source to the receiver? |
|                           | Inv. 2, Part 4, Step 11: Assess progress: performance assessment |
|                           | Inv. 4, Part 4, Step 1: Review reflect with a demonstration |
|                           | **Inv. 4, Part 4, Step 2: Move the book to a new position** |
|                           | Inv. 4, Part 4, Step 8: Assess progress: performance assessment |

|                           | Inv. 3, Part 1, Step 12: Assess progress: performance assessment |
|                           | Inv. 3, Part 1, Step 14: Have a sense-making discussion |
|                           | **Inv. 3, Part 2, Step 17: Predict what may happen next** |
|                           | Inv. 3, Part 2, Step 24: Add survival to the content grid |

|                           | Inv. 2, Part 3, Step 2: Demonstrate the spoon-gong system |
|                           | Inv. 2, Part 4, Step 11: Assess progress: performance assessment |
|                           | **Inv. 4, Part 4, Step 2: Move the book to a new position** |
|                           | Inv. 4, Part 4, Step 8: Assess progress: performance assessment |

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### Grades K–2 Crosscutting Concept Statements

**Structure and function**

The shape and stability of structures of natural and designed objects are related to their function(s).

**Stability and change**

Some things stay the same while other things change.

### Air and Weather Module

**Inv. 1, Part 2, Step 8:** Have a sense-making discussion

**Inv. 1, Part 2, Step 25:** Assess progress: performance assessment

**Inv. 1, Part 2, Step 26:** Record results

**Inv. 1, Part 2, Step 2:** Introduce structure and function

**Inv. 1, Part 2, Step 16:** Share notebook entries

**Inv. 1, Part 3, Step 13:** Record growth and label straws

**Inv. 1, Part 3, Step 16:** Discuss wheat growth after 2 weeks

**Inv. 2, Part 1, Step 17:** Have a sense-making discussion

**Inv. 2, Part 2, Step 17:** Assess progress: performance assessment

**Inv. 2, Part 2, Step 21:** Share notebook entries

**Inv. 2, Part 3, Step 2:** Discuss soil

**Inv. 3, Part 2, Step 24:** Add survival to the content grid

**Inv. 3, Part 3, Step 13:** View online activity: “Sorting Animals by Structures”

**Inv. 3, Part 3, Step 14:** Share notebook entries

**Inv. 3, Part 4, Step 17:** Discuss the reading

**Inv. 4, Part 2, Step 1:** Discuss roots

**Inv. 4, Part 2, Step 11:** Assess progress: performance assessment

**Inv. 4, Part 2, Step 13:** Continue reading “Changes in the Sky”

**Inv. 4, Part 3, Step 8:** Focus question: How does the temperature and weather change over the seasons?

**Inv. 2, Part 2, Step 19:** Discuss sunrise and sunset

**Inv. 2, Part 3, Step 9:** Have a sense-making discussion

**Inv. 2, Part 4, Step 14:** Have a sense-making discussion

**Inv. 4, Part 2, Step 13:** Continue reading “Changes in the Sky”

**Inv. 4, Part 3, Step 8:** Focus question: How does the temperature and weather change over the seasons?
### Sound and Light Module

- Inv. 1, Part 2, Step 2: Introduce *structure and function*
- Inv. 1, Part 2, Step 16: Share notebook entries
- Inv. 1, Part 3, Step 13: Record growth and label straws
- Inv. 1, Part 3, Step 16: Discuss wheat growth after 2 weeks
- Inv. 2, Part 1, Step 17: Have a sense-making discussion
- Inv. 2, Part 2, Step 17: Assess progress: performance assessment
- Inv. 2, Part 2, Step 21: Share notebook entries
- Inv. 2, Part 3, Step 2: Discuss soil
- Inv. 3, Part 2, Step 24: Add survival to the content grid
- Inv. 3, Part 3, Step 13: View online activity: “Sorting Animals by Structures”
- Inv. 3, Part 3, Step 14: Share notebook entries
- Inv. 3, Part 4, Step 17: Discuss the reading
- Inv. 4, Part 2, Step 1: Discuss roots
- Inv. 4, Part 2, Step 11: Assess progress: performance assessment

### Plants and Animals Module

- Inv. 1, Part 2, Step 2: Introduce *structure and function*
- Inv. 1, Part 2, Step 16: Share notebook entries
- Inv. 1, Part 3, Step 13: Record growth and label straws
- Inv. 1, Part 3, Step 16: Discuss wheat growth after 2 weeks
- Inv. 2, Part 1, Step 17: Have a sense-making discussion
- Inv. 2, Part 2, Step 17: Assess progress: performance assessment
- Inv. 2, Part 2, Step 21: Share notebook entries
- Inv. 2, Part 3, Step 2: Discuss soil
- Inv. 3, Part 2, Step 24: Add survival to the content grid
- Inv. 3, Part 3, Step 13: View online activity: “Sorting Animals by Structures”
- Inv. 3, Part 3, Step 14: Share notebook entries
- Inv. 3, Part 4, Step 17: Discuss the reading
- Inv. 4, Part 2, Step 1: Discuss roots
- Inv. 4, Part 2, Step 11: Assess progress: performance assessment
REFERENCES


