INTRODUCTION TO PERFORMANCE EXPECTATIONS

“The NGSS are standards or goals, that reflect what a student should know and be able to do; they do not dictate the manner or methods by which the standards are taught. . . . Curriculum and assessment must be developed in a way that builds students’ knowledge and ability toward the PEs [performance expectations]” (Next Generation Science Standards, 2013, page xiv).

This chapter shows how the NGSS Performance Expectations were bundled in the Sound and Light Module to provide a coherent set of instructional materials for teaching and learning.

This chapter also provides details about how this FOSS module fits into the matrix of the FOSS Program (page 37). Each FOSS module K–5 and middle school course 6–8 has a functional role in the FOSS conceptual frameworks that were developed based on a decade of research on science education and the influence of A Framework for K–12 Science Education (2012) and Next Generation Science Standards (NGSS, 2013).

The FOSS curriculum provides a coherent vision of science teaching and learning in the three ways described by the NRC Framework. First, FOSS is designed around learning as a developmental progression, providing experiences that allow students to continually build on their initial notions and develop more complex science and engineering knowledge. Students develop functional understanding over time by building on foundational elements (intermediate knowledge). That progression is detailed in the conceptual frameworks.

Second, FOSS limits the number of core ideas, choosing depth of knowledge over broad shallow coverage. Those core ideas are addressed at multiple grade levels in ever greater complexity. FOSS investigations at each grade level focus on elements of core ideas that are teachable and learnable at that grade level.

Third, FOSS investigations integrate engagement with scientific ideas (content) and the practices of science and engineering by providing firsthand experiences.

Teach the module with the confidence that the developers have carefully considered the latest research and have integrated into each investigation the three dimensions of the Framework and NGSS, and have designed powerful connections to the Common Core State Standards for English Language Arts.

The NGSS Performance Expectations bundled in this module include:

- Physical Sciences
  - 1-PS4-1
  - 1-PS4-2
  - 1-PS4-3
  - 1-PS4-4

- Engineering, Technology, and Applications of Science
  - K-2-ETS1-1
  - K-2-ETS1-2
  - K-2-ETS1-3
DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has four core ideas in physical sciences.

PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC Framework for the grades K–2 grade band to keep the core ideas in a rich and useful context.

The performance expectations related to each core idea are taken from the NGSS for grade 1.

Disciplinary Core Ideas Addressed

The Sound and Light Module connects with the NRC Framework for the grades K–2 grade band and the NGSS performance expectations for grade 1. The module focuses on core ideas for physical sciences and engineering design with some core ideas related to information processing by animals through senses (life sciences).

Physical Sciences

Framework core idea PS4: Waves and their applications in technologies for information transfer—How are waves used to transfer energy and information?

- **PS4.A: Wave properties**
  What are the characteristic properties and behaviors of waves? [Sound can make matter vibrate, and vibrating matter can make sound.]

- **PS4.B: Electromagnetic radiation**
  What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there? [Objects can be seen only when light is available to illuminate them. Very hot objects give off light (e.g., a fire, the Sun). Some materials allow light to pass through them, others allow only some light through, and others block all the light and create a dark shadow on any surface beyond them (i.e., on the other side from the light source), where the light cannot reach. Mirrors and prisms can be used to redirect a light beam. Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.]

- **PS4.C: Information technologies and instrumentation**
  How are instruments that transmit and detect waves used to extend human senses? [People use their senses to learn about the world around them. Their eyes detect light, their ears detect sound, and they can feel vibrations by touch. People also use a variety of devices to communicate (send and receive information) over long distances.]

The following NGSS grade 1 performance expectations for PS4 are derived from the Framework disciplinary core ideas above.

- **1-PS4-1.** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. [Clarification Statement: Examples of vibrating materials that make sound could include tuning forks and plucking a stretched string. Examples of how sound can
Introduction to Performance Expectations

make matter vibrate could include holding a piece of paper near a speaker making sound and holding an object near a vibrating tuning fork.

• 1-PS4-2. Make observations to construct an evidence-based account that objects can be seen only when illuminated. [Clarification Statement: Examples of observations could include those made in a completely dark room, a pinhole box, and a video of a cave explorer with a flashlight. Illumination could be from an external light source or by an object giving off its own light.]

• 1-PS4-3. Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light. [Clarification Statement: Examples of materials could include those that are transparent (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror).] [Assessment Boundary: Assessment does not include the speed of light.]

• 1-PS4-4. Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance. [Clarification Statement: Examples of devices could include a light source to send signals, paper cup and string “telephones,” and a pattern of drum beats.] [Assessment Boundary: Assessment does not include technological details for how communication devices work.]

Life Sciences

Framework core idea LS1: From molecules to organisms: structures and processes—How do organisms live, grow, respond to their environment, and reproduce?

• LS1.D: Information processing
  How do organisms detect, process, and use information about the environment? [Animals have body parts that capture and convey different kinds of information needed for growth and survival—for example, eyes for light, ears for sounds, and skin for temperature or touch. Animals respond to these inputs with behaviors that help them survive (e.g., find food, run from a predator).]

The following NGSS grade 1 performance expectations for LS1 is derived from the Framework disciplinary core ideas above.

• 1-LS1-1. Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.

NOTE
The Sound and Light Module provides students with experiences about how animals use their eyes and ears, and so it addresses DCI LS1.D. However, the associated performance expectation, 1-LS1-1, is addressed in the grade 1 Plants and Animals Module.
Engineering, Technology, and Applications of Science

Framework core idea ETS1: Engineering design—How do engineers solve problems?

- **ETS1.A:** Defining and delimiting an engineering problem
  What is a design for? What are the criteria and constraints of a successful solution? [A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. Asking questions, making observations, and gathering information are helpful in thinking about problems. Before beginning to design a solution, it is important to clearly understand the problem.]

- **ETS1.B:** Developing possible solutions
  What is the process for developing potential design solutions? [Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. To design something complicated, one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan.]

- **ETS1.C:** Optimizing the design solution
  How can the various proposed design solutions be compared and improved? [Because there is always more than one possible solution to a problem, it is useful to compare designs, test them, and discuss their strengths and weaknesses.]

The following NGSS grades K–2 performance expectations for ETS1 are derived from the Framework disciplinary core ideas above.

- **K-2-ETS1-1.** Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

- **K-2-ETS1-2.** Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

- **K-2-ETS1-3.** Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.
Framework core idea ETS2: Links among engineering, technology, science, and society—How are engineering, technology, science, and society interconnected?

- ETS2.A: Interdependence of science, engineering, and technology
  What are the relationships among science, engineering, and technology? [People encounter questions about the natural world every day. There are many types of tools produced by engineering that can be used in science to help answer these questions through observation or measurement. Observations and measurements are also used in engineering to help test and refine design ideas.]

- ETS2.B: Influence of engineering, technology, and science on society and the natural world
  How do science, engineering, and the technologies that result from them affect the ways in which people live? How do they affect the natural world? [People depend on various technologies in their lives; human life would be very different without technology. Every human-made product is designed by applying some knowledge of the natural world and is built by using materials derived from the natural world, even when the materials are not themselves natural—for example, spoons made from refined metals. Thus, developing and using technology has impacts on the natural world.]

No separate performance expectations are described for core idea ETS2 (see Next Generation Science Standards, 2013, volume 2, appendix J, for an explanation and elaboration).
SCIENCE AND ENGINEERING PRACTICES
A Framework for K–12 Science Education (National Research Council, 2012) describes eight science and engineering practices as essential elements of a K–12 science and engineering curriculum. Six practices are incorporated into the learning experiences in the Sound and Light Module.

The learning progression for this dimension of the framework is addressed in Next Generation Science Standards, 2013, volume 2, appendix F. Elements of the learning progression for practices recommended for grade 1 as described in the performance expectations appear in bullets below each practice.

Science and Engineering Practices Addressed

1. **Asking questions and defining problems**
   - Define a simple problem that can be solved through the development of a new or improved object or tool.

2. **Developing and using models**
   - Compare models to identify common features and differences.
   - Develop and/or use a model to represent amounts, relationships, relative scales, and/or patterns in the natural and designed world(s).

3. **Planning and carrying out investigations**
   - Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.
   - Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.
   - Make predictions based on prior experiences.

4. **Analyzing and interpreting data**
   - Record information (observations, thoughts, and ideas).
   - Use and share pictures, drawings, and/or writings of observations.
   - Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems.

5. **Constructing explanations and designing solutions**
   - Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena.

6. **Obtaining, evaluating, and communicating information**
   - Read grade-appropriate texts and/or use media to obtain scientific and/or technical information to determine patterns in and/or evidence about the natural and designed world(s).
   - Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.
Crosscutting Concepts Addressed

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

**Cause and effect**
- Events have causes that generate observable patterns.
- Simple tests can be designed to gather evidence to support or refute student ideas about causes.

**Systems and system models**
- Systems in the natural and designed world have parts that work together.

Connections: Understandings about the Nature of Science

**Science addresses questions about the natural and material world.**
- Scientists study the natural and material world.

**Scientific knowledge is based on empirical evidence.**
- Scientists look for patterns and order when making observations about the world.

**Scientific investigations use a variety of methods.**
- Scientists use different ways to study the world.

Connections: Science, Technology, Society, and the Environment

**Interdependence of science, engineering, and technology**
- Science and engineering involve the use of tools to observe and measure things.

**Influence of engineering, technology, and science on society and the natural world**
- Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials.

CROSSCUTTING CONCEPTS

A Framework for K–12 Science Education describes seven crosscutting concepts as essential elements of a K–12 science and engineering curriculum. The crosscutting concepts listed here are those recommended for grade 1 in the NGSS and are incorporated into the learning opportunities in the Sound and Light Module.

The learning progression for this dimension of the framework is addressed in Next Generation Science Standards, 2013, volume 2, appendix G. Elements of the learning progression for crosscutting concepts recommended for grade 1, as described in the performance expectations, appear after bullets below each concept.

CONNECTIONS

See Next Generation Science Standards, 2013, volume 2, appendix H and appendix J, for more on these connections.

For details on learning connections to Common Core State Standards for English Language Arts and Math, see the chapters FOSS and Common Core ELA—Grade 1 and FOSS and Common Core Math—Grade 1 in Teacher Resources.
SOUND AND LIGHT — Framework and NGSS

FOSS CONCEPTUAL FRAMEWORK

In the last half decade, teaching and learning research has focused on learning progressions. The idea behind a learning progression is that core ideas in science are complex and wide-reaching, requiring years to develop fully—ideas such as the structure of matter or the relationship between the structure and function of organisms. From the age of awareness throughout life, matter and organisms are important to us. There are things students can and should understand about these core ideas in primary school years, and progressively more complex and sophisticated things they should know as they gain experience and develop cognitive abilities. When we as educators can determine those logical progressions, we can develop meaningful and effective curricula for students.

FOSS has elaborated learning progressions for core ideas in science for kindergarten through grade 8. Developing a learning progression involves identifying successively more sophisticated ways of thinking about a core idea over multiple years.

If mastery of a core idea in a science discipline is the ultimate educational destination, then well-designed learning progressions provide a map of the routes that can be taken to reach that destination. . . . Because learning progressions extend over multiple years, they can prompt educators to consider how topics are presented at each grade level so that they build on prior understanding and can support increasingly sophisticated learning. (National Research Council, A Framework for K–12 Science Education, 2012, p. 26)

The FOSS modules are organized into three domains: physical science, earth science, and life science. Each domain is divided into two strands, as shown in the table “FOSS Next Generation—K–8 Sequence.” Each strand represents a core idea in science and has a conceptual framework

- Physical Science: matter; energy and change
- Earth and Space Science: dynamic atmosphere; rocks and landforms
- Life Science: structure and function; complex systems

The sequence in each strand relates to the core ideas described in the NRC Framework. Modules at the bottom of the table form the foundation in the primary grades. The core ideas develop in complexity as you proceed up the columns.

TEACHING NOTE

FOSS has conceptual structure at the module and strand levels. The concepts are carefully selected and organized in a sequence that makes sense to students when presented as intended.
Information about the FOSS learning progression appears in the **conceptual frameworks** (page 39 and 45), which shows the structure of scientific knowledge taught and assessed in this module, and the **content sequence** (pages 46–47), a graphic and narrative description that puts this single module into a K–8 strand progression.

FOSS is a research-based curriculum designed around the core ideas described in the NRC Framework. The FOSS module sequence provides opportunities for students to develop understanding over time by building on foundational elements or intermediate knowledge leading to the understanding of core ideas. Students develop this understanding by engaging in appropriate science and engineering practices and exposure to crosscutting concepts. The FOSS conceptual frameworks therefore are more detailed and finer grained than the set of goals described by the NGSS performance expectations (PEs). The following statement reinforces the difference between the standards as a blueprint for assessment and a curriculum, such as FOSS.

_Some reviewers of both public drafts [of NGSS] requested that the standards specify the intermediate knowledge necessary for scaffolding toward eventual student outcomes. However, the NGSS are a set of goals. They are PEs for the end of instruction—not a curriculum. Many different methods and examples could be used to help support student understanding of the DCIs and science and engineering practices, and the writers did not want to prescribe any curriculum or constrain any instruction. It is therefore outside the scope of the standards to specify intermediate knowledge and instructional steps._ (Next Generation Science Standards, 2013, volume 2, p. 342)
BACKGROUND FOR THE CONCEPTUAL FRAMEWORK in Sound and Light

There are two conceptual frameworks for the disciplinary core ideas in this module for grade 1—one with a focus on physical sciences and one on engineering design. In addition, this module provides experiences to strengthen the life science ideas about information processing—that animals have ears and eyes that detect and convey different kinds of information important to survival.

What Is Sound?

An ancient philosophical question asks, “If a tree falls in the forest when no one is around, does it make a sound?” The usual first response is to say, “Sure, something as big as a tree will certainly make a loud crash when it falls.” But maybe not. First we have to consider an even more fundamental question: What is sound? Is sound real and tangible, with an existence independent of a listener, or is sound a sensory process totally dependent on a living interpreter? To answer these questions, let’s review what we know about sound.

Sound is energy. The branch of physics that is concerned with sound is acoustics. Sound can be generated, it can move from one place to another, it can do work, and it dissipates over time and distance. Some sounds carry tremendous amounts of energy—the explosion of the volcano Krakatoa was heard 10,000 kilometers (km) away. Other sounds, like the plop of a pebble dropped into a pond, have almost no energy at all. No matter what their level of energy, all sounds behave in the same predictable ways.

Think about the triangle that was in the box of musical instruments when you were in elementary school. When you hang it up by the string and give it a tap with a stick, the familiar bright tone rings out. Clearly the sound is coming from the triangle, so we can refer to it as a sound source. Inside your ear, a complex sequence of mechanical and neurological processes receive and interpret the sounds emanating from the triangle. Your ear is a sound receiver. The triangle can be heard from above, below, or any other direction because sound travels in every direction from a source.

Close observation of the ringing triangle reveals an important fact—it’s moving. While the triangle is sounding, it is moving back and forth very rapidly, a movement called vibration. When the stick hits the triangle, it transfers energy to the metal, which starts to vibrate. When the energy in the metal is eventually used up, or transferred to another
object (such as when you touch the triangle), the sound stops. The sound will continue only as long as there is energy in the system to keep it going.

**How Sound Gets Around**

Sounds can travel from one place to another through thin air. They can also travel through gases other than air, through liquids, and even through solids. The only thing that sound can’t travel through is a vacuum. The process by which sound moves from one point to another point is called sound transfer, and that process requires a medium, something to travel through.

A vibrating object moves back and forth. When it moves in one direction, it pushes on the air molecules next to it, thus, compressing them, or packing them together more closely than usual. When the vibrating object moves in the other direction, it leaves in its wake an area that has fewer air molecules than usual. It goes back the other way to create another area of compression, and so forth. The energy in a compression area transfers to molecules nearby as the air expands, and the effect passes from molecule to molecule in this manner. These compression and rarefaction waves emanate from a vibrating object until the energy needed to create the waves is exhausted.

The same processes transmit sound through liquids and solids, but things happen a little faster. The molecules in liquids are closer together than the molecules in gases, and the molecules in solids are closest of all. Transfer of energy from one molecule to another can happen much more efficiently when the molecules are closer together to begin with. Also, the warmer a material is, the faster its molecules are moving, and the more efficient energy transfer is. With this information as a base, you could guess that sound travels slower high in Earth’s atmosphere than just above the surface of the ocean.

**CONCEPTUAL FRAMEWORK**

**Physical Science, Matter:  Sound and Light**

**Energy Transfer and Conservation**

**Concept C**

Waves are a repeating pattern of motion that transfer energy from place to place without displacement of matter. Electromagnetic waves can be detected over a wide range of frequencies; some can be observed by humans, others can be detected by designed technologies.

- **Sound.** Vibration is a rapid back-and-forth motion. Sound always comes from a source that is vibrating. Ears are sound detectors or receivers.
- **Sound.** Sound vibrations travel through objects and air.
- **Sound.** Volume is how loud or soft a sound is; loud sounds have more energy.
- **Sound.** Pitch is how high or low a sound is. High-pitched sounds come from objects that are short and vibrate quickly. Low-pitched sounds come from longer objects that vibrate more slowly.
- **Light.** Light sources are objects or systems that radiate light; light travels away from a source in all directions. Eyes are light detectors or receivers. Objects can be seen if light is available to illuminate them or if they give off their own light.
- **Light.** Shadows are the dark areas that result when light is blocked. The length and direction of a shadow depends on the position of the light source. Some materials block light entirely or partially; other materials allow light to travel through.
- **Light.** Mirrors can be used to redirect light.
- **Light and sound** convey information. Communication devices use light and sound.
**Characteristics of Sound**

Sounds can be loud or soft. They can sound high and piping or low and booming. These two characteristics of sound are known as amplitude and frequency, but in more common parlance they are known as volume and pitch.

Volume is a measure of the amount of energy in the sound—the more energy, the louder the sound. More energy means more molecules of air (or other medium) get put into motion. The relative amount of energy in sounds is measured in decibels. A secret whispered in your ear is about 10 decibels, a classroom full of active first graders doing hands-on science is about 50 decibels, and a jackhammer breaking up the sidewalk is about 100 decibels. Sounds registering in the region of 120 decibels, such as jet airliners taking off or live rock music, can cause pain, and prolonged exposure to sounds over 90 decibels can lead to hearing loss.

Pitch is a product of the rate (or frequency) of vibrations. The faster the vibrations, the higher the pitch of the sound. Conversely, the slower the vibrations, the lower the pitch of the sound. Named after Heinrich R. Hertz (1857–1894), the German physicist who discovered electromagnetic waves, hertz (Hz) refers to the number of vibrations in a second. Therefore, a 50 Hz sound comes from a source that is vibrating 50 times a second.

Musical instruments demonstrate the acoustics of pitch wonderfully. Think about a xylophone with its mathematically designed bars laid out from long to short. Any object, when energized so that it begins to vibrate, has its own frequency. This natural vibration frequency is the resonance frequency for that object. This frequency is determined by a number of factors, including the material the object is made of, its size and shape, and its tension. The xylophone bars are usually all made from the same metal stock, varying only in length. As you tap the bars in series, starting with the longest one, you will hear that the pitch of each successive bar is higher than the previous one. The general rule is the shorter the object, the higher the pitch.

That rule holds up with just about all musical instruments. A guitar player makes higher-pitched sounds by placing a finger on the string to shorten it. The saxophone player presses down on the keys to close the holes, making the column of vibrating air longer. The pitch goes down. Short piano strings make high tinkling sounds, and the percussionist’s largest timpani drum makes a low booming sound.
You may encounter the words ultrasonic and infrasonic from time to
time. Ultra means “beyond,” and infra means “below.” It follows that an
ultrasonic sound is a sound beyond sound—an apparent contradiction.
But such designations usually refer to human hearing. Humans with
fully functional hearing can hear sounds between about 15 Hz and
20,000 Hz per second. Higher frequencies are not perceived by the
human ear, so they are collectively referred to as ultrasonic sounds.
Dogs and cats, however, can hear sounds as high as 30,000 Hz, and bats
an incredible 100,000 Hz. On the other hand, whales and elephants are
able to communicate using infrasonic sounds, less than 15 Hz.

**Hearing Sounds**

Humans detect sound with a complex structure: the ear. The visible
portion is the outer ear, which acts like a funnel to channel sound
waves into the more sensitive parts of the ear deep inside the head.

Sounds travel down the ear tube until they
reach the eardrum, causing it to vibrate.
The vibrations of the eardrum pass through
an intricate mechanical system composed
of the three smallest bones in the body,
the hammer, anvil, and stirrup, so named
because they resemble those objects. Along
with the eardrum, they make up the middle
ear.

The bones of the middle ear connect to a
tiny spiral-shaped canal that contains hair
cells surrounded by fluid. This canal is the
inner ear. As the middle–ear bones vibrate,
they cause the fluid in the inner ear to
vibrate. This in turn causes the hair cells to
vibrate. The hair cells each connect directly
to a nerve that sends its impulses to the
brain. The brain interprets these impulses as sound.

This brings us back to where we started. When the tree falls in the
forest, it sets up waves that travel through the air until they eventually
run out of energy. But if no one is there with an ear to the wind, does
the falling tree make a sound?
Light

Light is an electromagnetic radiation. The primary source of light is a radiant object. The most familiar radiant object is the Sun, but lamp filaments, flames, flashes of electricity, and fireflies are also primary sources of light. These objects make light.

Light starts from a vibrating charge, like an electron. The vibration creates waves of energy that stream out in all directions. They are called electromagnetic waves. The size of the wave depends on the rate of vibration of the source charge. Rapidly vibrating charges have a lot of energy, and the high-frequency waves they produce have a lot of energy, too.

All electromagnetic waves, regardless of their frequency, travel at the speed of light (299,792 km per second) in straight lines until they hit something. The different frequencies of light waves, called wavelengths, are organized into the electromagnetic spectrum. The longest wavelengths are the low-energy radio frequencies. A single radio wave can be a meter or more long. At the other end of the spectrum are the high-energy X-rays and gamma rays, with tiny wavelengths that are billionths of a centimeter. Right in the center of the spectrum is a narrow slice of wavelengths known as visible light. The wavelengths of visible light range from 0.00004 centimeters (cm) (violet) to 0.00007 cm (red). It is this small range of wavelengths that humans exploit for vision. We cannot see longer wavelengths (infrared and longer) or shorter wavelengths (ultraviolet and shorter), although we can feel infrared radiation as heat and sense the effects of ultraviolet radiation when we get a painful sunburn.
**Vision**

The human eye has evolved photosensors (modified neurons called rods and cones) that turn visible light into electric pulses, which are processed in the brain to affect what we know as vision. Vision is a direct response to light interacting with photoreceptors.

Light can come from a primary source (radiant object) or a secondary source (an object that reflects light). Reflected light is a little different from what we usually consider a reflection, like that from a window or mirror. Reflected light hits an object and is not absorbed, but bounces off in a new direction. Trees, books, people, oranges, shoes, and every other nonluminous object we see all reflect light.

Light coming from the Sun is a mixture of frequencies of light. The flood of light includes red, yellow, green, blue, orange, and every other color of light mixed together. The net result is white light. When white light falls on an orange, the orange absorbs wavelengths of light selectively, and reflects the rest. The orange reflects only orange light, so that is what enters our eye. And the orange looks . . . orange! Tree leaves reflect only green light, stop signs absorb everything but red, and so on. That’s what happens when white light falls on an object.

**Shadows**

Opaque objects block light and produce an area where light is excluded. The dark area is a shadow. Shadows seen on Earth during the day look black, but they are actually dark gray. Objects placed in the shadow of a car or tree are easily seen because of scattering. Light interacts with gas molecules in the atmosphere and gets scattered and redirected in all directions. The result is that light waves always fill in the shadows to some extent.

**Reflection**

When light strikes a smooth, flat surface, one of two things will happen: it will pass through (be transmitted) or it will bounce off (be reflected). If the surface reflects most of the light falling on it, we call the surface a mirror. What we see reflected from a mirror is an image. An image is not real, but it is a good representation of reality; it looks real.

Mirrors allow us to see into places where our eyes usually cannot see, such as behind us and around corners. With mirrors we can gaze into our own eyes and inspect our own teeth. In addition, mirrors let us check pictures to see if they are symmetrical, and let us produce multiple images of a single object.
**Engineering Design**

Science is a discovery activity, a process for producing new knowledge. Scientific knowledge advances when scientists observe objects and events, think about how their observations relate to what is known, test their ideas in logical ways, and generate explanations that integrate the new information into understanding of the natural world. Thus the scientific enterprise is both what we know (content knowledge) and how we come to know it (practices). Scientists engage in a set of practices as they do their work, and these are the same practices students use in their science investigations.

Engineers apply that understanding of the natural world to solve real-world problems. Engineering is the systematic approach to finding solutions to problems identified by people in societies. The fields of science and engineering are mutually supportive, and scientists and engineers collaborate in their work. Often, acquiring scientific data requires designing and producing new technologies—tools, instruments, machines, and processes—to perform specific functions. The practices that engineers use are very similar to science practices but also involve defining problems and designing solutions.

The process of engineering design, while it involves engineering practices, is considered a separate set of disciplinary core ideas in the NRC Framework and in the NGSS. There are three basic ideas of engineering design: defining the problem, developing possible solutions, and comparing solutions to improve the design.

**Defining the problem** involves asking questions and making observations to obtain information about designing a specific object or tool. In this module, students learn about how sound travels through solids and use that information to design a string-cup telephone.

**Developing possible solutions** involves making decisions about the materials available and thoughtfully creating a design that describes how the materials can be used. Students should communicate their solutions orally and with drawings and words.

**Comparing different solutions** to improve the design involves testing several designs to see how well each one meets the challenge. First graders are not expected to conduct tests with controlled variables, but they should be able to determine if an object or tool, such as a cup and string telephone, meets the challenge and if not, how it might be improved. Identifying the differences between design solutions is
important. Students need to know that failure is not only OK, but expected in engineering design. Having something fail drives you to improve the system and make progress. Collaboration is an important aspect of engineering design; learning from the successes and failures of other design groups can be very productive.

In this module, there are two investigations in which students explore the disciplinary core ideas of engineering design in the context of building and testing communication devices with sound and light. But students engage in engineering practices in other investigations without engaging in the full engineering design process. FOSS has a continuum of engagements in engineering practices and process, from short experiences to more in-depth experiences where students reflect on the core ideas about the design process.

### CONCEPTUAL FRAMEWORK

**Engineering Design: Sound and Light**

**Concept A**

Defining and delimiting engineering problems.

- Asking questions, making observations, and gathering information are helpful in thinking about a problem. Before beginning to design a solution, it is important to clearly understand the problem.

**Concept B**

Developing possible solutions.

- Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solutions to other people.
- A great variety of objects can be built up from a small set of pieces.
- Different properties are suited to different purposes.

**Concept C**

Optimizing the design solution.

- Because there is always more than one possible solution to a problem, it is useful to compare and test designs.
Energy and Change Content Sequence

This table shows the three FOSS modules and courses that address the content sequence “energy and change” for grades K–8 with a focus on energy transfer and conservation dealing with waves. The supporting elements in each module (somewhat abbreviated) are listed. The elements for the Sound and Light Module are expanded to show how they fit into the sequence.

<table>
<thead>
<tr>
<th>Module or course</th>
<th>Motion and Stability: Forces and Interactions</th>
<th>Energy Transfer and Conservation</th>
</tr>
</thead>
</table>
| Waves (middle school) | • A simple wave has a repeating pattern of wavelength, frequency, and amplitude, all of which are related to the energy transferred by the wave.  
• Mechanical waves (like sound) require a medium through which they are transmitted.  
• Waves interacting with a medium can be absorbed, reflected, or transmitted through the medium.  
• A wave model can be used to explain the properties of light (brightness, color, and frequency-dependent bending). Because light can travel through space, it cannot be a mechanical wave.  
• Light travels in straight lines, except at the interface between transparent media where refraction occurs.  
• Electromagnetic waves form a spectrum of different wavelengths. Some electromagnetic radiation (visible light) can be detected by humans. An object can be seen when light reflected from its surface enters the eye.  
• Information technologies are instruments that transmit and detect waves to extend human senses. Design engineers must understand both the properties of the wave signal and its interaction with matter.  
• Digitized signals (sent as wave pulses) provide a reliable way to encode and transmit information. | |
| Energy (grade 4) | • Magnets interact with each other and with materials that contain iron.  
• Like poles of magnets repel each other; opposite poles attract.  
• Conductors are materials through which electric current can flow; all metals are conductors.  
• Any change of motion requires a force.  
• Patterns of motion can be observed; when there are regular patterns of motion, future patterns can be predicted. | • Electricity transfers energy that can produce heat, light, sound, and motion.  
• A circuit is a system that includes a complete pathway through which electric current flows.  
• Energy can be generated by burning fossil fuels or harnessing renewable energy.  
• The faster an object is moving, the more energy it has. In a collision, motion of one object can transfer to motion of other objects.  
• Waves are a repeating pattern of motion that transfer energy.  
• An object is seen when light from an object enters and is detected by the eye. |
| Sound and Light (grade 1) | | |
NOTE

See the Assessment chapter at the end of this Investigations Guide for more details on how the FOSS embedded and benchmark assessment opportunities align to the conceptual frameworks and the learning progressions. In addition, the Assessment chapter describes specific connections between the FOSS assessments and the NGSS performance expectations.

The NGSS performance expectations addressed in this module include:

Physical Sciences
1-PS4-1
1-PS4-2
1-PS4-3
1-PS4-4

Engineering, Technology, and Applications of Science
K–2-ETS1-1
K–2-ETS1-2
K–2-ETS1-3

See pages 30–33 in this chapter for more details on the grade 1 NGSS performance expectations.

Energy Transfer and Conservation

- Sound comes from vibrating objects; vibrations are rapid back-and-forth motions.
- Volume is how loud or soft a sound is; loud sounds have more energy.
- Large objects vibrate slowly and produce low-pitched sounds; small objects vibrate quickly and produce high-pitched sounds. Ears are sound receivers.
- Light sources are objects or systems that radiate light; light travels away from a source in all directions. Eyes are light detectors or receivers. Objects can be seen if light is available to illuminate them or if they give off their own light.
- Shadows are the dark areas that result when light is blocked. The length and direction of a shadow depends on the position of the light source.
- Mirrors can be used to redirect light.
- Communication devices use light and sound.
## Connections to NGSS by Investigation

### Science and Engineering Practices

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Planning and carrying out investigations</th>
<th>Analyzing and interpreting data</th>
<th>Constructing explanations</th>
<th>Obtaining, evaluating, and communicating information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inv. 1: Sound and Vibrations</strong></td>
<td></td>
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<tr>
<td><strong>Inv. 2: Changing Sound</strong></td>
<td>Asking questions and defining problems</td>
<td>Developing and using models</td>
<td>Planning and carrying out investigations</td>
<td>Analyzing and interpreting data</td>
</tr>
<tr>
<td></td>
<td>Constructing explanations and designing solutions</td>
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</tr>
<tr>
<td></td>
<td>Obtaining, evaluating, and communicating information</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Connections to Common Core State Standards for ELA

| Standard | RI 1: Ask and answer questions about key details in a text. | RI 2: Identify the main topic and retell key details of a text. | RI 4: Ask and answer questions to help determine or clarify the meaning of words and phrases in a text. | RI 5: Know and use text features. | RI 6: Distinguish between information provided by illustrations and by words. | RI 7: Use the illustrations and details in the text to describe its key ideas. | RI 8: Identify the reasons an author gives to support points. | RI 10: Read informational texts. | W 5: Respond to questions and suggestions from peers and add details to strengthen writing. | SL 1: Participate in collaborative conversations. | SL 2: Ask and answer questions about information presented orally or through other media. | SL 3: Ask and answer questions about what a speaker says. | L 5: Demonstrate understanding of word relationships and nuances in word meanings. |
|-----------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| **RI 1: Ask and answer questions about key details in a text.** | | | | | | | | | | | | | |
| **RI 2: Identify the main topic and retell key details of a text.** | | | | | | | | | | | | | |
| **RI 4: Ask and answer questions to help determine or clarify the meaning of words and phrases in a text.** | | | | | | | | | | | | | |
| **RI 5: Know and use text features.** | | | | | | | | | | | | | |
| **RI 6: Distinguish between information provided by illustrations and by words.** | | | | | | | | | | | | | |
| **RI 7: Use the illustrations and details in the text to describe its key ideas.** | | | | | | | | | | | | | |
| **RI 8: Identify the reasons an author gives to support points.** | | | | | | | | | | | | | |
| **RI 10: Read informational texts.** | | | | | | | | | | | | | |
| **W 5: Respond to questions and suggestions from peers and add details to strengthen writing.** | | | | | | | | | | | | | |
| **SL 1: Participate in collaborative conversations.** | | | | | | | | | | | | | |
| **SL 2: Ask and answer questions about information presented orally or through other media.** | | | | | | | | | | | | | |
| **SL 3: Ask and answer questions about what a speaker says.** | | | | | | | | | | | | | |
| **L 5: Demonstrate understanding of word relationships and nuances in word meanings.** | | | | | | | | | | | | | |
## Disciplinary Core Ideas

### PS4.A: Wave properties
- Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-1)

### PS4.C: Information technologies and instrumentation
- People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-4)

### LS1.D: Information processing
- Animals have body parts that capture and convey different kinds of information needed for growth and survival. Animals respond to these inputs with behaviors that help them survive.

## Crosscutting Concepts

- **Cause and effect**

### ETS1.A: Defining and delimiting engineering problems
- Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)

### ETS1.B: Developing possible solutions
- Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solution to other people. (K-2-ETS1-2)

### ETS1.C: Optimizing the design solution
- Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (K-2-ETS1-3)

- **Patterns**
- **Cause and effect**
- **Systems and system models**
<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Connections to Common Core State Standards for ELA</th>
</tr>
</thead>
</table>
| Planning and carrying out investigations  
Analyzing and interpreting data  
Constructing explanations  
Obtaining, evaluating, and communicating information | RF 4: Read with sufficient accuracy and fluency to support comprehension.  
RI 1: Ask and answer questions about key details in a text.  
RI 2: Identify the main topic and retell key details of a text.  
RI 3: Describe the connection between pieces of information in a text.  
RI 7: Use illustrations and details to describe its key ideas.  
RI 8: Identify the reasons an author gives to support points.  
RI 9: Identify similarities in and differences between two texts on the same topic.  
SL 1: Participate in collaborative conversations.  
SL 2: Ask and answer questions about information presented orally or through other media.  
SL 4: Describe events with relevant details. |
| Asking questions and defining problems  
Developing and using models  
Planning and carrying out investigations  
Analyzing and interpreting data  
Constructing explanations and designing solutions  
Obtaining, evaluating, and communicating information | F 4: Read with sufficient accuracy and fluency to support comprehension.  
RI 1: Ask and answer questions about key details in a text.  
RI 2: Identify the main topic and retell key details of a text.  
RI 3: Describe the connection between pieces of information in a text.  
RI 4: Ask and answer questions to help determine or clarify the meaning of words and phrases in a text.  
RI 5: Know and use text features.  
RI 6: Distinguish between information provided by illustrations and by words.  
RI 7: Use illustrations and details to describe its key ideas.  
RI 8: Identify the reasons an author gives to support points.  
RI 10: Read informational texts.  
W 5: Respond to questions and suggestions from peers, and add details to strengthen writing.  
SL 1: Participate in collaborative conversations.  
SL 4: Describe events with relevant details.  
L 6: Use acquired words and phrases. |
## Disciplinary Core Ideas

### PS4.B: Electromagnetic radiation
- Some materials allow light to pass through them, others allow only some light through, and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (1-PS4-3)

### PS4.B: Electromagnetic radiation
- Objects can be seen only when light is available to illuminate them. Some objects give off their own light. (1-PS4-2)
- Some materials allow light to pass through them, others allow only some light through, and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (1-PS4-3)

### PS4.C: Information technologies and instrumentation
- People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-4)

### LS1.D: Information processing
- Animals have body parts that capture and convey different kinds of information needed for growth and survival. Animals respond to these inputs with behaviors that help them survive.

## Crosscutting Concepts

### Patterns
- Cause and effect

### ETS1.A: Defining and delimiting engineering problems
- Before beginning to design a solution, it is important to clearly understand the problem. (K-2-ETS1-1)

### ETS1.B: Developing possible solutions
- Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem’s solution to other people. (K-2-ETS1-2)

### ETS1.C: Optimizing the design solution
- Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (K-2-ETS1-3)
## RECOMMENDED FOSS NEXT GENERATION K–8 SCOPE AND SEQUENCE

### Integrated Middle Grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Physical Science</th>
<th>Earth Science</th>
<th>Life Science</th>
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<tr>
<td>6–8</td>
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<tr>
<td></td>
<td>Heredity and Adaptation*</td>
<td>Electromagnetic Force*</td>
<td>Waves*</td>
</tr>
<tr>
<td></td>
<td>Chemical Interactions</td>
<td>Earth History</td>
<td>Populations and Ecosystems</td>
</tr>
<tr>
<td></td>
<td>Weather and Water</td>
<td>Diversity of Life</td>
<td>Human Systems Interactions*</td>
</tr>
<tr>
<td>5</td>
<td>Mixtures and Solutions</td>
<td>Earth and Sun</td>
<td>Living Systems</td>
</tr>
<tr>
<td>4</td>
<td>Energy</td>
<td>Soils, Rocks, and Landforms</td>
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<td>3</td>
<td>Motion and Matter</td>
<td>Water and Climate</td>
<td>Structures of Life</td>
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<td>Solids and Liquids</td>
<td>Pebbles, Sand, and Silt</td>
<td>Insects and Plants</td>
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<td>1</td>
<td>Sound and Light</td>
<td>Air and Weather</td>
<td>Plants and Animals</td>
</tr>
<tr>
<td>K</td>
<td>Materials and Motion</td>
<td>Trees and Weather</td>
<td>Animals Two by Two</td>
</tr>
</tbody>
</table>

*Half-length courses

- Physical Science content
- Earth Science content
- Life Science content
- Engineering content

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