INTRODUCTION

By middle school, students have heard about waves but likely have had little science instruction on the topic. This is developmentally appropriate, because the fundamental characteristics that describe wave behavior and properties are described in terms of mathematical relationships and graphical models that are best suited for students in middle school. The anchor phenomenon for this course is energy transfer by waves.

This puts teachers of FOSS Waves in an exciting position, with the opportunity to delve into new content and challenge students to think about concepts they have never considered before. And the content of FOSS Waves is equally exciting to students as they manipulate springs and lasers to determine properties that eventually will be used to explain how their cell phones work. The classroom will be abuzz with excitement throughout this course.

The course proceeds from the most concrete observations, those of physical properties of mechanical waves, to the most abstract concepts, by which students develop a model of electromagnetic waves. Students will also delve into engineering applications and real-life connections along the way. Students leave this course with a greater appreciation and understanding of modern communications technology and a solid foundation for high school and college physics. The driving question for the course is how is energy transferred through waves?

FOSS Waves is a 6-week course.

The NGSS Performance Expectations bundled in this course include:

Physical Sciences
MS-PS4-1
MS-PS4-2
MS-PS4-3

Engineering Design
MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
## WAVES — Overview

### Make Waves
**Students** measure their pulse under different circumstances to think about frequency. They create waves using metal springs. They use these simple waves to explore the fundamental properties of waves: wavelength, frequency, and amplitude.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Time</th>
<th>Guiding and Focus Questions for Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make Waves</td>
<td></td>
<td>&quot;What are the properties of all waves?&quot;</td>
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<td></td>
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<td><strong>Part 1</strong> Pulse Rate, 1 session</td>
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<td></td>
<td></td>
<td>What is frequency?</td>
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<td><strong>Part 2</strong> Spring Waves, 4 sessions</td>
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<tr>
<td></td>
<td></td>
<td>What defines a wave?</td>
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| Inv. 1     |      | **Activities** 5 sessions *                |
|           |      | **Assessment** 1 session                   |

### Wave Energy
**Students** learn about wave energy and compare energy in waves with different properties. Students look at an engineering failure and consider the work engineers must do to achieve a successful design. They use these ideas to develop a chamber that can effectively block sound waves.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Time</th>
<th>Guiding and Focus Questions for Phenomena</th>
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<tbody>
<tr>
<td>Wave Energy</td>
<td></td>
<td>&quot;How do mechanical waves interact with matter?&quot;</td>
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<td><strong>Part 1</strong> Energy in Waves, 2 sessions</td>
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<td>What is the relationship between wave properties and wave energy?</td>
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<td><strong>Part 2</strong> Bridge Collapse, 2 sessions</td>
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<td></td>
<td>How are engineering challenges solved?</td>
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<td><strong>Part 3</strong> Energy in Sound Waves, 4 sessions</td>
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<tr>
<td></td>
<td></td>
<td>What is the best way to insulate a recording studio from outside sounds?</td>
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</table>

| Inv. 2     |      | **Activities** 8 sessions                  |
|           |      | **Assessment** 1–2 sessions                |

* A class session is 45–50 minutes.
### Course Matrix

<table>
<thead>
<tr>
<th>Content and Disciplinary Core Ideas</th>
<th>Literacy/Technology</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waves Course—FOSS Next Generation</strong></td>
<td><strong>Science Resources Book</strong></td>
<td><strong>Benchmark Assessment</strong></td>
</tr>
<tr>
<td>* A wave is a back-and-forth pattern of motion that transfers energy. * Key features of waves are crests, troughs, and nodes. * Waves can be described in terms of wavelength, frequency, and amplitude. * If you know the frequency and wavelength, you can calculate the speed of a wave.</td>
<td>“Transverse and Compression Waves”</td>
<td>Entry-Level Survey</td>
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<td></td>
<td><strong>Online Activity</strong></td>
<td><strong>NGSS Performance Expectations</strong></td>
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<td></td>
<td>“Metronome” (optional)</td>
<td>MS-PS4-1</td>
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<td></td>
<td><strong>Video</strong></td>
<td><strong>MS-ETS1-1</strong></td>
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<td><em>Standing Wave</em></td>
<td><strong>MS-ETS1-2</strong></td>
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<td><strong>MS-ETS1-3</strong></td>
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<td><strong>MS-ETS1-4</strong></td>
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<td></td>
<td><strong>Science Resources Book</strong></td>
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<td></td>
<td>“Ocean Waves”</td>
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<td>“Tsunamist”</td>
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<td></td>
<td>“The Tacoma Narrows Bridge Disaster”</td>
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<td>“Engineering Design Process”</td>
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<td></td>
<td>“Sound Waves”</td>
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<td></td>
<td>“Acoustic Engineering”</td>
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<td></td>
<td><strong>Online Activity</strong></td>
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<td></td>
<td>“Oscilloscope”</td>
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<td><strong>Videos</strong></td>
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<td><em>Big Waves</em></td>
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<td></td>
<td><em>Tacoma Narrows Bridge Collapse 1</em></td>
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<td></td>
<td><em>Tacoma Narrows Bridge Collapse 2</em></td>
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<td></td>
<td><em>Soundproof Engineering</em></td>
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</table>
### Light Waves
Students explore properties of light waves. They start by using mirrors to explore reflection. Students use spectrometers to analyze spectra of visible light and learn more about the electromagnetic spectrum. They use filters to change the spectrum of a light source and to learn about color. Finally, they determine how refraction changes the path of light rays as they travel between media.

**Activities**
8 sessions *

**Guiding and Focus Questions for Phenomena**

- **How do electromagnetic waves interact with matter?**
  - Part 1 Mirrors, 2 sessions
    - What happens when light waves interact with matter?
  - Part 2 Spectra, 2 sessions
    - What do spectra reveal about light?
  - Part 3 Color, 2 sessions
    - Student-generated question, e.g., What makes objects appear as different colors?
  - Part 4 Refraction, 2 sessions
    - What happens to light waves at the interface between different media?

### Communication Waves
Students learn how information can be encoded and sent as digital waves to transfer large amounts of information efficiently over large distances. They test properties of fiber-optic cables to develop an understanding of how total internal reflection allows data transfer by light. Students learn how data is encoded and sent as modulated waves to a recipient for demodulation. Students create digital waves and develop an understanding of how digital waves enable modern communications.

**Active Inv.**
7 sessions

**Guiding and Focus Questions for Phenomena**

- **How can waves be used to transmit information over large distances?**
  - Part 1 Optical Fibers, 2 sessions
    - What are some design constraints in fiber-optic communications?
  - Part 2 Sending Sound, 2 sessions
    - How is sound sent through radio waves?
  - Part 3 Sending Images, 2 sessions
    - How are images sent through radio waves?

* A class session is 45–50 minutes.
## Course Matrix

### Content and Disciplinary Core Ideas

- A wave model can be used to explain the properties of light.
- Light travels in straight lines, except at the interface between transparent media where refraction occurs.
- The angle of reflection equals the angle of incidence.
- The electromagnetic spectrum extends beyond visible light.
- Different wavelengths of visible light are perceived as different colors.
- When light shines on an object, the light is reflected, absorbed, or transmitted through the object.

- Light can be transmitted long distances through optical fibers.
- Complex information like words, sound, and images must be encoded to be sent as light.
- Digital waves can have the same information as analog waves; digital waves can be improved by using smaller increments.
- Many modern communication devices use digitized signals (sent as waves) as a reliable way to encode and transmit information.
- Modern technology encodes information to improve transmission quality, reliability, and speed.

### Literacy/Technology

- **Science Resources Book**
  - “Reflecting on Light”
  - “Electromagnetic Spectra”
  - “Electromagnetic Radiation and Human Health”
  - “Throw a Little Light on Sight!”
  - “Seismic Waves”

- **Online Activity**
  - “Refraction”

- **Science Resources Book**
  - “Lasers”
  - “Digital Communication”
  - “Telecommunication: From Telegraph to Smartphone”

- **Online Activity**
  - “Digitized Images”

- **Video**
  - Fiber Optics

### Assessment

- **Benchmark Assessment**
  - Investigation 3 I-Check
  - Investigation 4 I-Check Posttest

- **NGSS Performance Expectation**
  - MS-PS4-2
  - MS-PS4-3
FOSS MIDDLE SCHOOL COMPONENTS

Teacher Toolkit

Each course comes with a Teacher Toolkit. The Teacher Toolkit is the most important part of the FOSS Program. It is here that all the wisdom and experience contributed by hundreds of educators has been assembled. Everything we know about the content of the course, how to teach the subject, and the resources that will assist the effort are presented here. Each middle school toolkit has three parts.

Investigations Guide. This spiral-bound document contains these chapters.

- Overview
- Framework and NGSS
- Materials
- Technology
- Investigations (four in this course)
- Assessment

Investigation 4: Communication Waves

15. Revise the focus question
   Ask students to answer the focus question. Have students share their answers. Encourage students to define the terms and to identify the structure of a wave. Ask students to lead a discussion on their observations to open the page you will be looking at.

What to Look For
   - Students explain that sounds sent as radio waves must be demodulated or digital waves to be sent by radio waves.
   - Students explain that sounds sent as radio waves can be modulated or digital waves to be sent by radio waves.
   - Students explain that sounds sent as radio waves can be recorded.
   - Students explain that sounds sent as radio waves can be transmitted through a network.
   - Students explain that sounds sent as radio waves can be transmitted through a network.

WRAP-UP/WARM-UP

16. Review notebook entries
   Ask students to return to the focus question. Have students explain what sounds sent as radio waves must be demodulated or digital waves to be sent by radio waves. Have students write about their understanding of the concept of communication waves. Ask students to return to the focus question. Have students explain what sounds sent as radio waves must be demodulated or digital waves to be sent by radio waves. Have students write about their understanding of the concept of communication waves.

17. Extend the investigation with homework
   Students can investigate waves or sound waves and how communication technology works. They can be assigned homework that requires them to use their knowledge of the topic. They can be asked to write a summary of the investigation and to describe how the technology works. They can be asked to write a summary of the investigation and to describe how the technology works. They can be asked to write a summary of the investigation and to describe how the technology works. They can be asked to write a summary of the investigation and to describe how the technology works.

MATERIALS for
Part 3: Sending Images

Provided equipment
- FOSS Science Resources: Waves
- Digital Communication
- "Telecommunication: From Telegraph to Smartphone"
- FOSS Science Resources: Waves

Part 3: Sending Images

- Teacher Toolkit
- Investigation 4: Communication Waves
- Investigations Guide
- Digital Communication
- "Telecommunication: From Telegraph to Smartphone"
- FOSS Science Resources: Waves
**FOSS Middle School Components**

**FOSS Science Resources book.** One copy of the student book of readings is included in the *Teacher Toolkit*.

**Teacher Resources.** These chapters can be downloaded from FOSSweb and most are also in the bound *Teacher Resources* book.

- FOSS Program Goals
- Grade-Level Planning Guide
- Science and Engineering Practices
- Crosscutting Concepts and Integration
- Sense-Making Discussions for Three-Dimensional Learning
- Access and Equity
- Science Notebooks in Middle School
- Science-Centered Language Development in Middle School
- FOSS and Common Core ELA
- FOSS and Common Core Math
- Taking FOSS Outdoors
- Science Notebook Masters
- Teacher Masters
- Assessment Masters
- Notebook Answers

**Equipment for Each Course**

The FOSS Program provides the materials needed for the investigations in sturdy, front-opening drawer-and-sleeve cabinets. Inside, you will find high-quality materials packaged for a class of 32 students. Consumable materials are supplied for five sequential uses (five periods in one day) before you need to restock. You will need to supply some items usually available in middle school science classrooms, and they are listed separately in the materials lists.

The middle school equipment kits are divided into unique permanent items, common permanent items, and consumable items. Speak to your FOSS sales representative about custom configuration to best address your classroom needs.
FOSS Science Resources Books

FOSS Science Resources: Waves is a book of original readings developed to accompany this course. The readings are referred to as articles in Investigations Guide. Students read the articles in the book as they progress through the course. Some readings are done in class; others are used as homework or for research projects. The articles cover specific concepts, usually after the concepts have been introduced in the active investigation.

The articles in FOSS Science Resources and the discussion questions provided in Investigations Guide help students make connections to the science concepts introduced and explored during the active investigations. Concept development is most effective when students are allowed to experience organisms, objects, and phenomena firsthand before engaging the concepts in text. The text and illustrations help make connections between what students experience concretely and the ideas that explain their observations.

Lasers

The laser is a valuable tool for testing properties of light waves. How does this tool create the special light beam that helps you conduct experiments? Let’s look inside a laser to find out.

Laser Beams

The light from a laser is very different from the light from a light bulb or flashlight. The laser produces a very narrow, focused beam. It is called coherent light. In coherent light, the waves are all the same length, so they are the same color. Coherent light waves are all in the same phase, so the peaks and troughs of the waves all line up. The laser’s coherent light has identical waves that travel together.

The term laser is an acronym for Light Amplification by Stimulated Emission of Radiation. As the name suggests, the key component of any laser is an optical amplifier—a device that strengthens the amplitude of light waves.
Technology

The FOSS website opens new horizons for educators and students in the classroom or at home. Each course has digital resources for students—interactive simulations, resources for research, and online activities. For teachers, FOSSweb provides resources for materials management, general teaching tools for FOSS, purchasing links, contact information for the FOSS Program, and technical support.

For each course, registered FOSSweb users can view teacher preparation videos, download editable teacher slides for classroom instruction, print or display digital duplication masters in English or Spanish, and get reports from the online assessment system, FOSSmap.

As a registered FOSSweb educator, you can customize your homepage, set up easy access to the digital components of the courses you teach, and create class pages for your students with access to activities and online assessments.

### Ongoing Professional Learning

The Lawrence Hall of Science and Delta Education strive to develop long-term partnerships with districts and teachers through thoughtful planning, effective implementation, and ongoing teacher support. FOSS has a strong network of consultants who have rich and experienced backgrounds in diverse educational settings using FOSS.

![Digitized Images](image-url)
FOSS INSTRUCTIONAL DESIGN

FOSS is designed around active investigation that provides engagement with science concepts and science and engineering practices. Surrounding and supporting those firsthand investigations are a wide range of experiences that help build student understanding of core science concepts and deepen scientific habits of mind.

The Elements of the FOSS Instructional Design

- Using Formative Assessment
- Integrating Science Notebooks
- Solving Real-World Problems and Engineering Challenges
- Engaging in Science–Centered Language Development
- Engaging with Technology
- Reading FOSS Science Resources Books

Active Investigation
Each FOSS investigation follows a similar design to provide multiple exposures to science concepts. The design includes these pedagogies.

- **Active investigation in collaborative groups**: firsthand experiences with phenomena in the natural and designed worlds
- **Recording in science notebooks** to answer a focus question dealing with the scientific phenomenon under investigation
- **Informational reading in FOSS Science Resources books**
- **Online activities** to acquire data or information or to elaborate and extend the investigation
- **Opportunities to apply knowledge** to solve problems through the engineering design process or to address regional ecological issues
- **Assessment** to monitor progress and motivate student learning

In practice, these components are seamlessly integrated into a curriculum designed to maximize every student’s opportunity to learn.

A **learning cycle** employs an instructional model based on a constructivist perspective that calls on students to be actively involved in their own learning. The model systematically describes both teacher and learner behaviors in a systematic approach to science instruction.

The most recent model employs a series of five phases of intellectual involvement known as the 5Es: engage, explore, explain, elaborate, and evaluate. The body of foundational knowledge that informs contemporary learning-cycle thinking has been incorporated seamlessly and invisibly into the FOSS curriculum design.

Engagement with real-world **phenomena** is at the heart of FOSS. In every part of every investigation, the central phenomenon is referenced implicitly in the focus question that guides instruction and frames the intellectual work. The focus question is a prominent part of each lesson and is called out for the teacher and student. The investigation Scientific and Historical Background section is organized by focus question—the teacher has the opportunity to read and reflect on the phenomenon in each part before preparing for the lesson. Students record the focus question in their science notebooks, and after exploring the phenomenon thoroughly, explain their thinking in words and drawings.

In science a phenomenon is a natural occurrence, circumstance, or structure that is perceptible by the senses—an observable reality. Scientific phenomena are not necessarily phenomenal (although they may be)—most of the time they are pretty mundane and well within the everyday experience. What FOSS does to enact an effective engagement with the NGSS is thoughtful selection of phenomena for students to investigate.

**NOTE**
The anchor phenomena establish the storyline for the course. The investigative phenomena guide each investigation part. Related examples of everyday phenomena are incorporated into the readings, videos, discussions, formative assessments, outdoor experiences, and extensions.
Active Investigation

Active investigation is a master pedagogy. Embedded within active learning are a number of pedagogical elements and practices that keep active investigation vigorous and productive. The enterprise of active investigation includes

- context: questioning and planning;
- activity: doing and observing;
- data management: recording, organizing, and processing;
- analysis: discussing and writing explanations.

**Context: questioning and planning.** Active investigation requires focus. The context of an inquiry can be established with a focus question about a phenomenon or challenge from you, or in some cases, from students—What defines a wave? At other times, students are asked to plan a method for investigation. This might include determining the important data to gather and the necessary tools. In either case, the field available for thought and interaction is limited. This clarification of context and purpose results in a more productive investigation.

**Activity: doing and observing.** In the practice of science, scientists put things together and take things apart, they observe systems and interactions, and they conduct experiments. This is the core of science—active, firsthand experience with objects, organisms, materials, and systems in the natural world. In FOSS, students engage in the same processes. Students often conduct investigations in collaborative groups of four, with each student taking a role to contribute to the effort.

The active investigations in FOSS are cohesive, and build on each other and the readings to lead students to a comprehensive understanding of concepts. Through the investigations, students gather meaningful data.

Online activities throughout the course provide students with opportunities to collect data, manipulate variables, and explore models and simulations beyond what can be done in the classroom. Seamless integration of the online activities forms an integral part of students’ active investigations in FOSS.

**Data management: recording, organizing, and processing.** Data accrue from observation, both direct (through the senses) and indirect (mediated by instrumentation). Data are the raw material from which scientific knowledge and meaning are synthesized. During and after work with materials, students record data in their notebooks. Data recording is the first of several kinds of student writing.
Students then organize data so that they will be easier to think about. Tables allow efficient comparison. Organizing data in a sequence (time) or series (size) can reveal patterns. Students process some data into graphs, providing visual display of numerical data. They also organize data and process them in the science notebook.

**Analysis: discussing and writing explanations.** The most important part of an active investigation is extracting its meaning. This constructive process involves logic, discourse, and existing knowledge. Students share their explanations for phenomena, using evidence generated during the investigation to support their ideas. They conclude the active investigation by writing in their notebooks a summary of their learning as well as questions raised during the activity.

**Science Notebooks**

Research and best practice have led us to place more emphasis on the student science notebook. Keeping a notebook helps students organize their observations and data, process their data, and maintain a record of their learning for future reference. The process of writing about their science experiences and communicating their thinking is a powerful learning device for students. And the student notebook entries stand as a credible and useful expression of learning. The artifacts in the notebooks form one of the core elements of the assessment system.

You will find the duplication masters for middle school presented in a notebook format. They are reduced in size (two copies to a standard sheet) for placement (glue or tape) in a bound composition book. Student work is entered partly in spaces provided on the notebook sheets and partly on adjacent blank sheets. Full-sized masters that can be filled in electronically and are suitable for projection are available on FOSSweb. Look to the chapter in Teacher Resources called Science Notebooks in Middle School for more details on how to use notebooks with FOSS.
Reading in FOSS Science Resources

Reading is a vital component of the FOSS Program. Reading enhances and extends information and concepts acquired through direct experience.

Readings are included in the FOSS Science Resources: Waves book. Students read articles as well as access data and information for use in investigations.

Some readings can be assigned as homework or extension activities, whereas other readings have been deemed important for all students to complete with a teacher’s support in class.

Each in-class reading has a reading guide embedded in Guiding the Investigation. The reading guide suggests breakpoints with questions to help students connect the reading to their experiences from class, and recommends notebook entries. Each of these readings also includes one or more prompts that ask students to make additional notebook entries. These prompts should help students who missed the in-class reading to process the article in a more meaningful way. Some of the most essential articles are provided as notebook masters. Students can highlight the article as they read, add notes or questions, and add the article to their science notebooks.

The FOSS and Common Core ELA chapter in Teacher Resources shows how FOSS provides opportunities to develop and exercise the Common Core ELA practices through science. A detailed table identifies these opportunities in the FOSS courses for middle school.

Integrating Technology through FOSSweb

The simulations and online activities on FOSSweb are designed to support students’ learning at specific times during instruction. Digital resources include streaming videos that can be viewed by the class or small groups.

The Technology chapter provides details about the online activities for students and the tools and resources for teachers to support and enrich instruction. There are many ways for students to engage with the digital resources—in class as individuals, in small groups, or as a whole class, and at home with family and friends.
Assessing Progress

The FOSS assessment system includes both formative and summative assessments. Formative assessment monitors learning during the process of instruction. It measures progress, provides information about learning, and is predominantly diagnostic. Summative assessment looks at the learning after instruction is completed, and it measures achievement.

Formative assessment in FOSS, called embedded assessment, is an integral part of instruction, and occurs on a daily basis. You observe action during class in a performance assessment or review notebooks after class. Performance assessments look at students’ engagement in science and engineering practices or their recognition of crosscutting concepts. Embedded assessment provides continuous monitoring of students’ learning and helps you make decisions about whether to review, extend, or move on to the next idea to be covered.

The embedded assessments are based on authentic work produced by students during the course of participating in the FOSS activities. Students do their science, and you look at their notebook entries. Bullet points in Guiding the Investigation tell you specifically what students should know and be able to communicate.

Benchmark assessments are short summative assessments given after each investigation. These I-Checks are actually hybrid tools: they provide summative information about students’ achievement, and because they occur soon after teaching each investigation, they can be used diagnostically as well. Reviewing specific items on an I-Check with the class provides additional opportunities for students to clarify their thinking.

If student work is incorrect or incomplete, you know that there has been a breakdown in learning or communications. The assessment system provides a menu of next-step strategies to resolve the situation. Embedded assessment is assessment for learning, not assessment of learning.

Assessment of learning is the domain of the benchmark assessments. Benchmark assessments are delivered at the beginning of the course (Entry-Level Survey) and at the end of the course (Posttest), and after each investigation (I-Checks). The benchmark tools are carefully crafted and thoroughly tested assessments composed of valid and reliable items. The assessment items do not simply identify whether a student knows a piece of science content. They also identify the depth to which students understand science concepts and principles and the extent to which they can apply that understanding.
Solving Real-World Problems
FOSS investigations introduce science content in the context of real-world applications, so that students develop an understanding of how scientific principles explain natural phenomena. By middle school, students can begin to apply this understanding of science to develop solutions to real-world problems. We ask students to consider problem-solving and engineering challenges that are precise in scope, giving students a thorough understanding of the problem and potential solutions. Students have clear criteria and constraints (in the case of engineering design challenges) and focused topics of research (in the case of research projects).

In life science, students explore local environments, issues of biodiversity, medical technology applications, and human impact upon ecosystems. In earth science, students consider natural resource supplies and demands, technological advances in space exploration, and human effects on Earth’s ocean and atmosphere. In physical science, students apply concepts of motion, kinetic energy, heat, and energy transfer in a series of engineering challenges where students develop and refine designs to solve an engineering problem.

Throughout all content areas, students have opportunities to collaborate and develop or select solutions to real-world issues. As described in the NRC Framework (2012, page 12), “engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to practical problems; doing so enhances their understanding of science—and, for many, their interest in science—as they recognize the interplay among science, engineering, and technology.” By providing students with ongoing opportunities to understand and engage with the application of science, we help students develop an appreciation of and enthusiasm for science.

Taking FOSS Outdoors
The true value of science knowledge is its usefulness in the real world and not just in the classroom. When students are able to transfer knowledge of scientific principles to natural systems, they experience a sense of accomplishment.

FOSS middle school courses provide outdoor activities and extensions. Teaching outdoors is the same as teaching indoors—except for the space. Because of the different space, new management procedures are required. Students can get farther away. Materials have to be transported. The space has to be defined and honored. Time has to be budgeted for getting to, moving around in, and returning from the outdoor study site. All these and more issues and solutions are discussed in the Taking FOSS Outdoors chapter in Teacher Resources on FOSSweb.
Science-Centered Language Development and Standards for Literacy in Science

The FOSS active investigations, science notebooks, FOSS Science Resources articles, and formative assessments provide rich contexts in which students develop and exercise thinking and communication. These elements are essential for effective instruction in both science and language arts—students experience the natural world in real and authentic ways and use language to inquire, process information, and communicate their thinking about scientific phenomena. FOSS refers to this development of language process and skills within the context of science as science-centered language development.

In the Science-Centered Language Development in Middle School chapter in Teacher Resources, we explore the intersection of science and language and the implications for effective science teaching and language development. Language plays two crucial roles in science learning: (1) it facilitates the communication of conceptual and procedural knowledge, questions, and propositions, and (2) it mediates thinking—a process necessary for understanding. Science provides a real and engaging context for developing literacy, and language-arts skills and strategies to support conceptual development and scientific practices. The skills and strategies used for enhancing reading comprehension, writing expository text, and exercising oral discourse are applied when students are recording their observations, making sense of science content, and communicating their ideas.

The most effective integration depends on the type of investigation, the experience of students, the language skills and needs of students, and the language objectives that you deem important at the time. The Science-Centered Language Development chapter is a library of resources and strategies for you to use. The chapter describes how literacy strategies are integrated purposefully into the FOSS investigations, gives suggestions for additional literacy strategies that both enhance students’ learning in science and develop or exercise English-language literacy skills, and develops science vocabulary with scaffolding strategies for supporting all learners. We identify effective practices in language-arts instruction that support science learning and examine how learning science content and engaging in science and engineering practices support language development.

Specific methods to make connections to the Common Core State Standards for Literacy in Science are included in the flow of Guiding the Investigation. These recommended methods are linked through ELA Connection notes. In addition, the FOSS and the Common Core ELA chapter in Teacher Resources summarizes all of the connections to each standard at the given grade level.
DIFFERENTIATED INSTRUCTION FOR ACCESS AND EQUITY

Learning from Experience

The roots of FOSS extend back to the mid-1970s and the Science Activities for the Visually Impaired and Science Enrichment for Learners with Physical Handicaps projects (SAVI/SELPH). As those special-education science programs expanded into fully integrated settings in the 1980s, hands-on science proved to be a powerful medium for bringing all students together. The subject matter is universally interesting, and the joy and satisfaction of discovery are shared by everyone. Active science by itself provides part of the solution to full inclusion and provides many opportunities at one time for differentiated instruction.

Many years later, FOSS began a collaboration with educators and researchers at the Center for Applied Special Technology (CAST), where principles of Universal Design for Learning (UDL) had been developed and applied. FOSS continues to learn from our colleagues about ways to use new media and technologies to improve instruction. Here are the UDL principles.

Principle 1. Provide multiple means of representation. Give learners various ways to acquire information and demonstrate knowledge.


FOSS for All Students

The FOSS Program has been designed to maximize the science learning opportunities for students with special needs and students from culturally and linguistically diverse origins. FOSS is rooted in a 35-year tradition of multisensory science education and informed by recent research on UDL. Procedures found effective with students with special needs and students who are learning English are incorporated into the materials and strategies used with all students. In addition, the Access and Equity chapter in Teacher Resources (or go to FOSSweb to download this chapter) provides strategies and suggestions for enhancing the science and engineering experiences for each of the specific groups noted above.
FOSS instruction allows students to express their understanding through a variety of modalities. Each student has multiple opportunities to demonstrate his or her strengths and needs. The challenge is then to provide appropriate follow-up experiences for each student. For some students, appropriate experience might mean more time with the active investigations or online activities. For other students, it might mean more experience building explanations of the science concepts orally or in writing or drawing. For some students, it might mean making vocabulary more explicit through new concrete experiences or through reading to students. For some students, it may be scaffolding their thinking through graphic organizers. For other students, it might be designing individual projects or small-group investigations. For some students, it might be more opportunities for experiencing science outside the classroom in more natural, outdoor environments.

**Assessment and Extensions**

The next-step strategies used during the self-assessment sessions after I-Checks provide many opportunities for differentiated instruction. For more on next-step strategies, see the Assessment chapter.

There are additional strategies for providing differentiated instruction. The FOSS Program provides formative assessment tools and strategies so that you know what students are thinking throughout the course. The Assessment chapter provides recommendations for how to engage students who are having difficulty with specific concepts. Online activities are effective tools to provide differentiated instruction. The extension activities are appropriate for students who need additional practice with the basic concepts as well as those ready for more advanced projects. Interdisciplinary extensions are listed at the end of each investigation. Use these ideas to meet the individual needs and interests of your students.

**English Learners**

The FOSS multisensory program provides a rich laboratory for language development for English learners. The program uses a variety of techniques to make science concepts clear and concrete, including modeling, visuals, and active investigations in small groups at centers. Key vocabulary is usually developed within an activity context with frequent opportunities for interaction and discussion between teacher and student and among students. This provides practice and application of the new vocabulary. Instruction is guided and scaffolded through
carefully designed lesson plans, and students are supported throughout. The learning is active and engaging for all students, including English learners.

Science vocabulary is introduced in authentic contexts while students engage in active learning. Strategies for helping all students read, write, speak, and listen are described in the Science-Centered Language Development chapter. There is a section on science-vocabulary development with scaffolding strategies for supporting English learners. These strategies are essential for English learners, and they are good teaching strategies for all learners.
FOSS INVESTIGATION ORGANIZATION

Courses are subdivided into investigations (four in this course). Investigations are further subdivided into two to four parts. Each investigation has a general guiding question for the phenomenon students investigate and each part of each investigation is driven by a specific focus question. The focus question, usually presented as the part begins, engages the student with the phenomenon and signals the challenge to be met, mystery to be solved, or principle to be uncovered. The focus question guides students’ actions and thinking and makes the learning goal of each part explicit for teachers over several class sessions. Each part concludes with students recording an answer to the focus question in their notebooks.

The investigation is summarized for the teacher in the At a Glance chart at the beginning of each investigation.

Investigation–specific scientific background information for the teacher is presented in each investigation chapter organized by the focus questions.

The Teaching and Learning about section makes direct connections to the NGSS foundation boxes for the grade level—Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts. This information is later presented in color-coded sidebar notes to identify specific places in the flow of the investigation where connections to the three dimensions of science learning appear. The section ends with a conceptual–flow graphic of the content.

The Materials and Getting Ready sections provide scheduling information and detail exactly how to prepare the materials and resources for conducting the investigation. The Quick Start table lists planning and preparation steps.

Teaching Notes and ELA Connections appear in blue boxes in the sidebars. These notes compose a second voice in the curriculum—an educative element. The first (traditional) voice is the message you deliver to students. The second (educative) voice, shared as a teaching note, is designed to help you understand the science content and pedagogical rationale at work behind the instructional scene. ELA Connection boxes show the relevant Common Core State Standards for English Language Arts.

The Getting Ready and Guiding the Investigation sections have features that are flagged in the sidebars. These include several icons to remind you when a particular pedagogical method is suggested, as well as concise bits of information in several categories.

FOCUS QUESTION

What is the relationship between wave properties and wave energy?

SCIENCE AND ENGINEERING PRACTICES

Using mathematics and computational thinking

DISCIPLINARY CORE IDEAS

PS4.A: Wave properties

CROSSCUTTING CONCEPTS

System and system models

TEACHING NOTE

This focus question can be answered with a simple yes or no, but the question has power when students support their answers with evidence. Their answers should take the form “Yes, because ____.”
The **safety** icon alerts you to potential safety issues related to chemicals, allergic reactions, and the use of safety goggles.

The small-group **discussion** icon asks you to pause while students discuss data or construct explanations in their groups.

The **vocabulary** icon indicates where students should review recently introduced vocabulary.

The **recording** icon points out where students should make a science-notebook entry.

The **reading** icon signals when the class should read a specific article in the *FOSS Science Resources* book.

The **technology** icon signals when the class should use a digital resource on FOSSweb.

The **assessment** icons appear when there is an opportunity to assess student progress using embedded or benchmark assessments. Some are performance assessments, indicated by an icon with a beaker and ruler.

The **outdoor** icon signals when to move the science learning experience into the schoolyard.

The **engineering** icon indicates opportunities for an experience incorporating engineering practices.

The **math** icon indicates an opportunity to engage in numerical data analysis and mathematics practice.

The **crosscutting concepts** icon indicates a key opportunity to integrate content between courses by using supports from the Crosscutting Concepts and Integration chapter in *Teacher Resources*.

The **homework** icon indicates science learning experiences that extend beyond the classroom.

The **EL note** provides a specific strategy to assist English learners in developing science concepts.

Look for the start of a new **session** within an investigation part.

**EL NOTE**

**SESSION 2  45–50 minutes**

Full Option Science System
CLASSROOM ORGANIZATION

FOSS has tried to anticipate the most likely learning environments in which science will be taught and designed the curriculum to be effective in those settings. The most common setting is the 1-hour period (45–55 minutes) every day, one teacher, in the science room. Students come in wave after wave, and they all learn the same thing. Some teachers may have two preps because they teach seventh-grade and eighth-grade classes. The Waves Course was designed to work effectively in this traditional hour-a-day format.

The 1-hour subdivisions of the course adapt nicely to the block-scheduling model. It is usually possible to conduct two of the 1-hour sessions in a 90-minute block because of the uninterrupted instructional period. A block allows students to set up an experiment and collect, organize, and process the data all in one sequence. Block scheduling is great for FOSS; students learn more, and teachers are responsible for fewer preps.

Interdisciplinary teams of teachers provide even more learning opportunities. Students will be using mathematics frequently and in complex ways to extract meaning from their inquiries. It has been our experience, however, that middle school students are not skilled at applying mathematics in science because they have had few opportunities to use these skills in context. In an interdisciplinary team, the math teacher can use student-generated data to teach and enhance math skills and application.

The integration of other subject areas, such as language arts, into the science curriculum is also enhanced when interdisciplinary teams are used.

Managing Time

Time is a precious commodity. It must be managed wisely in order to realize the full potential of your FOSS curriculum. The right amount of time should be allocated for preparation, instruction, discussion, assessment, research, and current events. Start from the premise that there will not be enough time to do everything, so you will have to budget selectively. Don’t scrimp on the prep time, particularly the first time you use the curriculum. Spend enough time with Investigations Guide to become completely familiar with the lesson plans. Take extra time at the start of the course to set up your space efficiently; you will be repaid many times over later. As you become more familiar with the FOSS Program and the handling of the materials, the proportion of time devoted to each aspect of the program may shift, so that you are spending more and more time on instruction and enrichment activities.
Effective use of time during the instructional period is one of the keys to a great experience with this course. *Investigations Guide* offers suggestions for keeping the activities moving along at a good pace, but our proposed timing will rarely exactly match yours. The best way we know for getting in stride with the curriculum is to start teaching it. Soon you will be able to judge where to break an activity or push in a little enrichment to fill your instructional period.

### Managing Space

The *Waves Course* will work in the ideal setting: flat-topped tables where students work with materials in groups of four; theater seating for viewing online activities (darkened); technology available for accessing the Internet and online activities, and other reference materials available. But we don’t expect many teachers to have the privilege of working in such a space. So we designed FOSS courses to work effectively in a number of typical settings, including the science lab and regular classroom. We have described, however, the minimum space and resources needed to use FOSS. Here’s the list, in order of importance.

- A computer with Internet access, and a large-screen display monitor or projector
- Tables or desks for students to work in groups of four
- A whiteboard, blackboard, or chart paper and marking pens
- A surface for materials distribution
- A place to clean and organize equipment
- A convenient place to store the kit
- A computer lab or multiple digital devices

Once the minimum resources are at hand, take a little time to set up your science area. This investment will pay handsome dividends later since everyone will be familiar with the learning setup.

- Organize your computer and projection system and be sure the Internet connection is working smoothly.
- Think about the best organization of furniture. This may change from investigation to investigation.
- Plan where to set up your materials stations.
- Know how students will keep notes and record data, and plan where students will keep their notebooks.
Managing Students
A typical class of middle school students is a wonderfully complex collection of personalities, including the clown, the athlete, the fashion statement, the worrier, the achiever, the pencil sharpener, the show-off, the reader, and the question-answerer. Notice there is no mention of the astrophysicist, but she could be in there, too. Management requires delicate coordination and flexibility—some days students take their places in an orderly fashion and sit up straight in their chairs, fully prepared to learn. Later in the week, they are just as likely to have the appearance of migrating waterfowl, unable to find their place, talkative, and constantly moving.

FOSS employs a number of strategies for managing students. Often a warm-up activity is a suitable transition from lunch or the excitement of changing rooms to the focused intellectual activities of the Waves Course. Warm-ups tend to be individual exercises that review what transpired yesterday with a segue to the next development in the curriculum. This gives students time to get out their notebooks, grind points on their pencils, settle into their space, and focus.

Students most often work in groups in this course. Groups of four are generally used, but at other times, students work in pairs.

Suggestions for guiding students’ work in collaborative groups are described later in this chapter.

When Students Are Absent
When a student is absent for a session, another student can act as a peer tutor and share the science notebook entries made for that day. The science notebooks should be a valuable tool for students to share in order to catch up on missed classes. Also consider giving him or her a chance to spend some time with the materials.

Students can use the resources on FOSSweb at school or at home for the missed class. And finally, allow the student to bring home FOSS Science Resources to read any relevant articles. Each article has a few review items that the student can respond to verbally or in writing.
Managing Technology

The Waves Course includes an online component. The online activities and materials are not optional. For this reason, it is essential that you have in your classroom at minimum one computer, a large-screen display monitor or projection system, and a connection to the Internet. Sometimes you will use multimedia to make presentations to the entire class. Sometimes small groups or individuals will use the online program to work simulations and representations, and to gather information. Plan on the students having access to computers or tablets for work in groups.

Option 1: The computer lab. If you have access to a lab where all students can work simultaneously as individuals, pairs, or small groups, schedule time in the lab for your classes. If you have access to a cart with a class set of devices, schedule that for your classroom.

Option 2: Classroom computers or other digital devices. With multiple devices for groups in the science classroom, you can set up a multitasking environment with half the students working with Internet resources and half engaged in reading or small-group discussions. Then swap roles. If every student or pair has access to a device, you are all set.

Option 3: Home access. Students can access FOSSweb from home by visiting www.FOSSweb.com and accessing the class pages with the account information you provide for student use. You must set up a class page for students to have home access to the multimedia.
Managing Materials

The Materials section lists the items in the equipment kit and any teacher-supplied materials. It also describes things to do to prepare a new kit and how to check and prepare the kit for your classroom. Individual photos of each piece of FOSS equipment are available for printing from FOSSweb, and can help students and you identify each item.

The FOSS Program designers suggest using a central materials distribution system. You organize all the materials for an investigation at a single location called the materials station. As the investigation progresses, one member of each group gets materials as they are needed, and another returns the materials when the investigation is complete. You place the equipment and resources at the station, and students do the rest. Students can also be involved in cleaning and organizing the materials at the end of a session.

The Materials list for each investigation is divided into these categories.

- Equipment provided in the FOSS kit
- Teacher-supplied items
- FOSSweb resources to be downloaded or projected

Each category is further subdivided by need.

- For each student
- For each group
- For the class
- For the teacher

The Getting Ready section begins with the Quick Start table to help you immediately know the schedule; what to preview, print, or copy; what materials to prepare; and what to plan for assessment. Preparation details linked to the Quick Start provide specific information.
ESTABLISHING A CLASSROOM CULTURE

Working in Collaborative Groups

Collaboration is important in science. Scientists usually collaborate on research enterprises. Groups of researchers often contribute to the collection of data, the analysis of findings, and the preparation of the results for publication.

Collaboration is expected in the science classroom, too. Some tasks call for everyone to have the same experience, either taking turns or doing the same things simultaneously. At other times, group members may have different experiences that they later bring together.

Research has shown that students learn better and are more successful when they collaborate. Working together promotes student interest, participation, learning, and self-confidence. FOSS investigations use collaborative groups extensively.

No single model for collaborative learning is promoted by FOSS. We can suggest, however, a few general guidelines that have proven successful over the years.

For most activities in middle school, collaborative groups of four in which students take turns assuming specific responsibilities work best. Groups can be identified completely randomly (first four names drawn from a hat constitute group 1), or you can assemble groups to ensure diversity. Thoughtfully constituted groups tend to work better.

Groups can be maintained for extended periods of time, or they can be reconfigured more frequently. For a short course, you might keep students in the same groups for the entire course.

Functional roles within groups can be determined by the members themselves, or they can be assigned in one of several ways. Each member in a collaborative group can be assigned a number or a color. Then you need only announce which color or number will perform a certain task for the group at a certain time. Compass points can also be used: the person seated on the east side of the table will be the Reporter for this investigation.

The functional roles used in the investigations follow. If you already use other names for functional roles in your class, use those in place of these in the investigations.
Getters are responsible for materials. One person from each group gets equipment from the materials station, and another person later returns the equipment.

One person is the Starter for each task. This person makes sure that everyone gets a turn and that everyone has an opportunity to contribute ideas to the investigation.

The Recorder collects data as it happens and makes sure that everyone has recorded information on his or her science notebook sheets.

The Reporter shares group data with the class or transcribes it to the board or class chart.

Getting started with collaborative groups requires patience, but the rewards are great. Once collaborative groups are in place, you will be able to engage students more in meaningful conversations about science content. You are free to “cruise” the groups, to observe and listen to students as they work, and to interact with individuals and small groups as needed.

**Norms for Sense-Making Discussions**

Setting up norms for discussion and holding yourself and your students accountable is the first step toward creating a culture of productive talk in the classroom that supports engagement in the science and engineering practices. Students need to feel free to express their ideas, and to provide and receive criticism from others as they work toward understanding of the disciplinary core ideas of science and methods of engineering.

Establish norms at the beginning of the school year. It is recommended that this be done together as a class activity. However, presenting a poster of norms to students and asking them to discuss why each one is important can also be effective. Before each sense-making discussion, review the norms. Review what it will look like, sound like, and feel like when everyone is following the agreements. You might have students work on one or two at a time as they are developing their oral discourse skills. After discussion, save a few minutes for reflection on how well the group or the class adhered to the norms and what they can do better next time. More strategies for supporting academic discourse can be found in the Sense-Making Discussions for Three-Dimensional Learning and Science-Centered Language Development in Middle School chapters in *Teacher Resources* (also available as downloadable PDFs on FOSSweb).
Collaborative Teaching and Learning

Collaborative learning requires a collective as well as individual growth mindset. A growth mindset is when people believe that their most basic abilities can be developed through dedication and hard work (see the research of Carol Dweck and her book *Mindset: The New Psychology of Success*). As students work together to make sense of phenomena and develop their inquiry and discourse skills, it’s important to recognize and value their efforts to try new approaches and their willingness to make their thinking visible. Remind students that everyone in the classroom, including you the teacher, will be learning new ideas and ways to think about the world. Where there is productive struggle, there is learning. Here are a few ways to help students develop a growth mindset for science and engineering.

- **Praise effort, not right answers**. When students are successful at a task, provide positive feedback about their level of engagement and effort in the practices, e.g., the efforts they put into careful observations, how well they organized and interpreted their data, the relevancy of their questions, how well they connected or applied new concepts, and their use of precise vocabulary, etc. Also, try to provide feedback that encourages students to continue to improve their learning and exploring, e.g., is there another way to approach this question? Have you thought about _____? What evidence is there to support _____?

- **Foster and validate divergent thinking**. During sense-making discussions, continually emphasize how important it is to share emerging ideas and to be open to the ideas of others in order to build understanding. Model for students how you refine and revise your thinking based on new information. Make it clear to students that the point is not for them to show they have the right answer, but rather to help each other arrive at new understandings. Point out positive examples of students expressing and revising their ideas.

Establishing a classroom culture that supports three-dimensional teaching and learning centers on collaboration. Collaborative groupings, materials management, and norms are structures you can put into place to foster collaboration. These structures along with the expectations that students will be negotiating meaning together as a community of learners, creates a learning environment where students are compelled to work, think, and communicate like scientists and engineers to help one another learn.
SAFETY IN THE CLASSROOM

Following the procedures described in each investigation will make for a very safe experience in the classroom. You should also review your district safety guidelines and make sure that everything that you do is consistent with those guidelines. The FOSS Science Safety poster is included in the kit for classroom use.

Look for the safety icon in the Getting Ready and Guiding the Investigation sections, which will alert you to safety considerations throughout the course.

Safety Data Sheets (SDS) for materials used in the FOSS Program can be found on FOSSweb. If you have questions regarding any SDS, call Delta Education at 1-800-258-1302 (Monday–Friday, 8 a.m. to 5 p.m. ET).

General classroom safety rules to share with students are listed here.

1. Always follow the safety procedures outlined by your teacher. Follow directions, and ask questions if you’re unsure of what to do.
2. Never put any material in your mouth. Do not taste any material or chemical unless your teacher specifically tells you to do so.
3. Do not smell any unknown material. If your teacher tells you to smell a material, wave a hand over it to bring the scent toward your nose.
4. Avoid touching your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals. Tell your teacher if you have any allergies.
5. Always wash your hands with soap and warm water immediately after using chemicals (including common chemicals, such as salt and dyes) and handling natural materials or organisms.
6. Do not mix unknown chemicals just to see what might happen.
7. Always wear safety goggles when working with liquids, chemicals, and sharp or pointed tools. Tell your teacher if you wear contact lenses.
8. Clean up spills immediately. Report all spills, accidents, and injuries to your teacher.
9. Treat animals with respect, caution, and consideration.
10. Never use the mirror of a microscope to reflect direct sunlight. The bright light can cause permanent eye damage.
FOSS CONTACTS

**General FOSS Program information**

www.FOSSweb.com
www.DeltaEducation.com/FOSS

**Developers at the Lawrence Hall of Science**

FOSS@berkeley.edu

**Customer Service at Delta Education**

www.DeltaEducation.com/contact.aspx
Phone: 1-800-258-1302, 8:00 a.m.–5:00 p.m. ET

**FOSSmap (online component of FOSS assessment system)**

http://FOSSmap.com/

**FOSSweb account questions/access codes/help logging in**

techsupport.science@schoolspecialty.com
Phone: 1-800-258-1302, 8:00 a.m.–5:00 p.m. ET

**School Specialty online support**

loginhelp@schoolspecialty.com
Phone: 1-800-513-2465, 8:30 a.m.–6:00 p.m. ET

**FOSSweb tech support**

support@FOSSweb.com

**Professional development**

www.FOSSweb.com/Professional-Development

**Safety issues**

www.DeltaEducation.com/SDS
Phone: 1-800-258-1302, 8:00 a.m.–5:00 p.m. ET
For chemical emergencies, contact Chemtrec 24 hours a day.
Phone: 1-800-424-9300

**Sales and replacement parts**

www.DeltaEducation.com/FOSS/buy
Phone: 1-800-338-5270, 8:00 a.m.–5:00 p.m. ET