INTRODUCTION

Astronomy is the study of everything we can observe and imagine beyond Earth—the Moon, the Sun, the solar system with all its planets and lesser objects, the Milky Way, and the vastness of the cosmos. Astronomers ask fundamental questions. When and where did the universe start? Why is it expanding? What is the destiny of the universe? Astronomers endeavor to answer these questions by determining the kinds and numbers of objects in the cosmos, the composition of those objects, their motions, and their interactions with one another. Because Earth is part of this ultimate system, the science of astronomy includes the study of our own planet.

Space—the vessel holding billions upon billions of swirling galaxies—is today’s final frontier. Astronomers are the pioneers who travel back in time along paths of light reaching out to Earth from stars millions of light-years distant. These celestial census takers and cartographers are creating an increasingly coherent picture of a universe abuzz with stars, many hosting families of orbiting planets.

And here we now stand on a small, rocky planet orbiting a typical star, in a typical galaxy, peering into the night sky with a sense of anticipation. There is a growing sense that we are probably not alone. Will we detect life in the universe in our lifetimes? When it does happen, those who share in the discovery will witness the opening of the next chapter in the amazing story of life.
### PLANETARY SCIENCE — Overview

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<td><strong>Where Am I?</strong></td>
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<td>1. School to Space</td>
<td>What can be seen from 100 m altitude? 1000 m? 10,000 m? How does the Moon change day by day?</td>
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<td>2. Moon Watch</td>
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<td><strong>A Round, Spinning Earth</strong></td>
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<td>Why is it hotter in the summer? Why are there more hours of sunlight in the summer?</td>
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<td><strong>Moon Study</strong></td>
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<td>What is visible on the Moon? What does a scaled Earth/Moon model look like?</td>
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<td>2. How Big/How Far?</td>
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<td><strong>Phases of the Moon</strong></td>
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<td>What Moon-phase patterns can be observed? What causes Moon phases?</td>
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</tbody>
</table>
| ● Location or position can be described in terms of a frame of reference.  
● Altitude is the distance above Earth’s surface.  
● Elevation is the distance above sea level.  
● The Moon can be observed both day and night. | **Science Notebook Entry**  
Quick write  
*Bird’s-Eye Views*  
*Moon Log* | **Benchmark Assessment**  
Survey (optional)  
**Embedded Assessment**  
Response sheet  
Scientific practices |
| ● Line of sight is the straight, unimpeded path taken by light from an object to an eye.  
● At all times, half of Earth is illuminated (day) and half is dark (night).  
● Daytime and nighttime are the result of Earth’s rotation on its axis.  
● Earth’s axis tilts at an angle of 23.5° and points toward the North Star. | **Science Notebook Entry**  
*Shape of Earth*  
*Day/Night Think Questions* | **Embedded Assessment**  
Response sheet  
Scientific practices  
Quick write  
**Benchmark Assessment**  
Investigations 1–2 I-Check |
| ● The tilt of Earth’s axis and Earth’s revolution around the Sun results in seasons.  
● Beam spreading affects the intensity of solar radiation on Earth’s surface.  
● The duration of daylight at a position on Earth’s surface varies as Earth revolves around the Sun, due to the tilt of Earth’s axis. | **Science Notebook Entry**  
*Beam Spreading*  
*Local Sunrise/Sunset Times*  
*Day-Length Questions*  
*Seasonal Changes*  
**Science Resources Book**  
“The First Voyage of Columbus” (optional)  
“Eratosthenes: First to Measure Earth” (optional) | **Embedded Assessment**  
Response sheets  
**Benchmark Assessment**  
Investigation 3 I-Check |
| ● The Moon has surface features that can be identified in telescope images.  
● Scale is the size relationship between a representation of an object and the object.  
● Scale can be expressed as a ratio when an object and its representation are measured in related units. | **Science Notebook Entry**  
*Moon-Picture Observations*  
*Questions about the Moon*  
*Moon Statistics*  
*Calculating a Scaling Factor*  
**Science Resources Book**  
“Lunar Myths” | **Embedded Assessment**  
Scientific practices |
| ● The Moon shines as a result of reflected light from the Sun. Half of the Moon is always illuminated (except during a lunar eclipse).  
● Moon phase depends on how much of the Moon’s illuminated surface is visible from Earth, which is determined by the relative positions of Earth and the Moon in their orbits around the Sun. | **Science Notebook Entry**  
Quick write  
*Looking at the Moon from Earth*  
**Science Resources Book**  
“The Measuring Time with Calendars”  
“Calculating the Observance of Ramadan”  
“Earth’s Moon” | **Embedded Assessment**  
Quick writes  
Scientific practices  
Response sheets  
**Benchmark Assessment**  
Investigations 4–5 I-Check |
### Planetary Science Overview

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<td><strong>Craters</strong></td>
<td><strong>Active Inv.</strong> 4 Sessions</td>
<td>1. Moon Craters 2. Target Earth</td>
<td>Are Moon craters the result of volcanoes or impacts?  Will Earth experience a major impact in the future?</td>
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<td><strong>Reading</strong> 1 Session</td>
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<td></td>
<td><strong>Assessment</strong> 1 Session</td>
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<tr>
<td><strong>Beyond the Moon</strong></td>
<td><strong>Active Inv.</strong> 2–3 Sessions</td>
<td>1. What’s Out There? 2. Origins</td>
<td>What is in the solar system? Where did the solar system come from?</td>
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<td></td>
<td><strong>Reading</strong> 2 Sessions</td>
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<tr>
<td><strong>The Solar System</strong></td>
<td><strong>Active Inv.</strong> 6 Sessions</td>
<td>1. Where Are the Planets? 2. Comparing Temperatures and Atmospheres 3. Where Is the Water?</td>
<td>Where are the planets in the solar system? Which planet is most like Earth? Where is there water in the solar system?</td>
</tr>
<tr>
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<td><strong>Assessment</strong> 1 Session</td>
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<tr>
<td><strong>Space Exploration</strong></td>
<td><strong>Active Inv.</strong> 4 Sessions</td>
<td>1. Light Spectra 2. Exploration of the Solar System</td>
<td>Why is light important in astronomy? What are the big questions that guide space exploration?</td>
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<td><strong>Assessment</strong> 1 Session</td>
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<tr>
<td><strong>Orbits and New Worlds</strong></td>
<td><strong>Active Inv.</strong> 4 Sessions</td>
<td>1. The Moons of Jupiter 2. Looking for Planets 3. What Is Our Cosmic Address?</td>
<td>What can be learned by studying the moons of Jupiter? How are planets outside the solar system found? What is our cosmic address?</td>
</tr>
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<td></td>
<td><strong>Assessment</strong> 1 Session</td>
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## Content

- Craters of various sizes and types result when meteoroids of various sizes impact the surface of planets and satellites.
- Craters can be categorized by size and physical characteristics: simple, complex, terraced, ringed (or basin), and flooded.
- Earth and the Moon have been, and continue to be, subjected to the same rate of bombardment by meteoroids.

- The solar system includes the Sun, planets and satellites, and a host of smaller objects.
- The solar system formed during a sequence of events that started with a nebula.
- The Moon formed after a massive collision between the forming Earth and a planetesimal about the size of Mars.

- The distance between solar system objects is enormous.
- Liquid water is essential for life as we know it.
- The temperature on a planet depends on two major variables: distance from the Sun and the nature of its mediating atmosphere.
- Images can convey information about liquid water on planetary surfaces.

- A spectroscope analyzes the wavelengths of light (spectrum) coming from a light source.
- Scientific missions provide data about the composition and environmental conditions on the planets, moons, and other bodies in the solar system.

- Planetary-system objects move in measurable and predictable patterns.
- A transit occurs when a planet passes between a star and an observer.
- The magnitude and duration of the dip in light intensity during a transit reveals information about the planet.

## Writing/Reading

- **Science Notebook Entry**
  - Crater Investigation Planning
  - Model Impact Craters
  - Asteroid Size and Impacts
  - Counting Major Impacts

- **Science Resources Book**
  - “Craters: Real and Simulated”
  - “The Impact That Ended the Reign of the Dinosaurs”

## Assessment

- **Embedded Assessment**
  - Scientific practices
  - Benchmark Assessment
  - Investigation 6 I-Check

- **Embedded Assessment**
  - Quick draws

- **Embedded Assessment**
  - Scientific practices
  - Science notebook entry
  - Benchmark Assessment
  - Investigations 7–8 I-Check

- **Embedded Assessment**
  - Scientific practices
  - Benchmark Assessment
  - Investigation 9 I-Check

- **Embedded Assessment**
  - Science notebook entry
  - Scientific practices
  - Benchmark Assessment
  - Posttest
Full Option Science System

PLANETARY SCIENCE — Overview

A FRAMEWORK FOR K–12 SCIENCE EDUCATION

The Planetary Science Course for grades 6–8 emphasizes the use of knowledge and evidence to construct explanations for the structures and motions of objects in the solar system. This course supports the following principles set forth in A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (National Research Council, 2011).

Scientific and Engineering Practices

Develop students’ abilities to do and understand scientific practices.

- Asking questions (for science) and defining problems (for engineering).
- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Developing and using models.
- Using mathematics, information and computer technology, and computational thinking.
- Constructing explanations (for science) and designing solutions (for engineering).
- Engaging in argument from evidence.
- Obtaining, evaluating, and communicating information.

Crosscutting Concepts

Develop students’ understandings of concepts that bridge disciplinary core ideas and provide an organizational framework for connecting knowledge from different disciplines into a coherent and scientifically based view of the world.

- Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
- Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
- Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
• **Systems and system models.** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

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

• **Stability and change.** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study.

**Earth and Space Sciences**

**Core Idea ESS1: Earth’s Place in the Universe**

- What is the universe, and what is Earth's place in it?
  - What is the universe, and what goes on in stars? (ESS1.A)
  - What are the predictable patterns caused by Earth's movement in the solar system? (ESS1.B)

**Core Idea ESS2: Earth’s Systems**

- How and why is Earth constantly changing?
  - How do the properties and movements of water shape Earth's surface and affect its systems? (ESS2.C)

**Physical Sciences**

**Core Idea PS2: Motion and Stability: Forces and Interactions**

- How can one explain and predict interactions between objects and within systems?
  - What underlying forces explain the variety of interactions observed? (PS2.B)

**Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer**

- How are waves used to transfer energy and information?
  - What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there? (PS4.B)
  - How are instruments that transmit and detect waves used to extend human senses? (PS4.C)
FOSS CONCEPTUAL FRAMEWORK

FOSS has conceptual structure at the course level. The concepts are carefully selected and organized in a sequence that makes sense to students when presented as intended. In the last half decade, research has been focused on learning progressions. The idea behind a learning progression is that core ideas in science are complex and wide-reaching—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 we can and should understand about them in our primary school years, and progressively more complex and sophisticated things we should know about them as we gain experience and develop our cognitive abilities. When we as educators can determine those logical progressions, we can develop meaningful and effective curriculum.

FOSS has elaborated learning progressions for core ideas in science for kindergarten through grade 8. Developing the learning progressions involves identifying successively more sophisticated ways of thinking about core ideas over multiple years. “If mastery of a core idea in science is the ultimate educational destination, learning progressions are the routes that can be taken to reach that destination” (National Research Council, A Framework for K–12 Science Education, 2011).

The FOSS modules (grades K–6) and courses (grades 6–8) are organized into three domains: physical science, earth science, and life science. Each domain is divided into two strands, which represent a core scientific idea, as shown in the columns in the table: matter/energy and change, dynamic atmosphere/rocks and landforms, structure and function/complex systems. The sequence of modules and courses in each strand relates to the core ideas described in the national 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.

In addition to the science content framework, every course provides opportunities for students to engage in and understand scientific practices, and many courses explore issues related to engineering practices and the use of natural resources.
The science content used to develop the FOSS courses describes what we want students to learn; the science and engineering practices describe how we want students to learn. Scientific inquiry involves a number of habits of mind and philosophical orientations, and these, too, will develop in richness and complexity as students advance through their science studies. Scientific inquiry is a behavior, so it can be assessed only while it is in progress. Thus, assessment of inquiry is based on teacher observation. The indicators of inquiry in progress include students involved in the many aspects of active thinking, students motivated to learn, and students taking responsibility for their own learning.
PLANETARY SCIENCE IN MIDDLE SCHOOL

A subject as huge as astronomy suggests the need for specialization. Some astronomers direct their powerful telescopes into deep space, looking for galaxies in the throes of birth or death to better understand the mysteries of the life cycles of huge systems. Others study the multitudes of stars and reservoirs of raw materials contained in our galaxy. Other teams of astronomers search for planets around distant stars, and some design elaborate Earth-based receivers to scan the universe for signs of extraterrestrial intelligence. But perhaps the most comprehensive body of astronomical knowledge has been accumulated by scientists who study the objects in our planetary system—the planets, satellites, and lesser objects and debris that orbit the Sun. Planetary science is the study of planets and their moons—their size, composition, and motion in relationship to one another, along with the other objects circling a star.

We tend to use the terms solar system and planetary system interchangeably. This is reasonable because until very recently we knew of only one planetary system—the one dominated by our star, Sol. However, solar system refers to a specific case of a planetary system—our case.

The solar system had its beginning about 4.57 billion years ago. The Sun and eight planets accreted from a modest accumulation of spiraling space debris—chunks, dust, and gases (including water)—spinning around in a region some considerable distance from the center of the Milky Way galaxy. At that time, the universe was already billions of years old. It is estimated that the Sun is in its midlife vitality, and will continue to function more or less in its present role for another 5 billion years. At that time, it will make a final grandstand display, expanding 250 times its present diameter (a red dwarf) as it exhausts its reserves of hydrogen fuel. Our burnt-out Sun will then decline and collapse into a kind of stellar corpse called a white dwarf, and the solar system as we know it will cease to exist.

The inquiry proposed in this course on planetary science will not progress in the direction just suggested, from the outermost reaches toward Earth. Rather, the sequence will start with our most familiar solar system object, Earth, and build out from there. The first extraterrestrial way station will be the Moon, followed by the other planets. This approach also recapitulates the rich history of discovery and philosophical reform that accompanied the introduction of what in those days were heretical notions of the origin and governance of celestial objects.
Why Study the Solar System?

**The Student’s Case.** It’s been heard so many times . . . the middle school student’s mantra: “Why do I have to learn this? What does this have to do with my life?” They ask these questions, not to be argumentative, but because they are awakening to a larger world and feeling the first sting of realization that soon they will have to make their way in it. “I’ll need a job, and I’m not going to be an astronaut. I really don’t want to do this.”

These questions betray the fact that middle school students have acquired a more complex worldview. They have progressed from a life guided by concrete experiences and events in the present to a more worldly view interwoven with powerful abstractions, extending from past to future. Now the curriculum can advance a level to take advantage of the new abilities of students. Students are now ready for planetary science.

Planetary science has a history and a future. The history is a fascinating progression of discoveries of objects and phenomena in near space—in large measure, a chronicle of the advance of technology. The history of our investigation of the solar system is a history of ideas—ideas reinforced through experimentation and observation. It is this dimension of the study of the solar system that will provide the greatest benefit to students: the opportunity to revisit the thinking behind the big ideas in planetary science.

As curriculum developers, we ask students to consider two questions as they investigate planetary science: What do you know? How do you know it? Students sometimes consider the first question to be the most important as it relates to science content, but really the second question is of equal or greater importance.

The second question contributes to thinking. How do you know Earth is round? The answer to the second question is personal, because it is through the internal processing of information, each in their own way, that students confirm their knowledge. This metacognitive process—thinking about your thinking—is hard, and students often resist, but the logical internal arguments that they develop to confirm their understanding are valuable.

Planetary science is excellent for exercising the emerging ability of middle school students to use inferential thinking. The study of planetary science reveals a history of ideas coalesced from indirect evidence rather than ideas built out of concrete experience. How did ancient astronomers conclude that Earth is round? What caused the craters on the Moon? Why are some surfaces of the Moon largely
flat and unmarred? Where did the Moon come from? How can you tell planets from stars? Throughout this course, students will find opportunities to propose explanations for objects, structures, and phenomena they encounter in their excursion through the solar system.

The Teacher’s Case. Middle school teachers know that middle school students are in a universe of turmoil. Bodies, emotions, and social relationships are at odds. One day (or minute) they will be composed and ready to learn—actually quite mature—and the next they will be hopelessly distracted and sensitive. On the settled days, students will engage in analytical problem solving, grappling effectively with abstractions. But on the squirrelly days, students will have better success with concrete experiences. Middle school students need both, and successful teachers know how to manage the balance of learning modalities to maximize student success.

The Planetary Science Course provides variety to keep both students and teachers interested. At different times, students work alone, in pairs, in groups of four, and as a class. Sometimes the activities are fairly rigorous, and other times the atmosphere is decidedly social. The tempo will vary (students shouldn’t be allowed to fall into predictable patterns), the teaching strategies will vary (middle school students think they get bored easily), the other students with whom they work will vary (social relationships rule middle school students’ lives), and the places where inquiry happens will vary (they love to be on the move).

The Planetary Science Course presents something interesting for every student. There is an opportunity for each student to shine and be a star.
Can I Teach This? I’m Not an Astronomer

FOSS assumes that teachers using this course possess no more than a minimal level of planetary-science content knowledge, a functional vocabulary of basic astronomy, and familiarity with the motions of the principal objects in the solar system—Earth, Moon, planets, and Sun. Additional knowledge is an asset but is not a prerequisite for teaching the course effectively. The specific content dealt with in each investigation is discussed in the Scientific and Historical Background section of each chapter. Teachers may not have a thorough understanding of the material when they start the course, but they will have a pretty good understanding of the objects and principles at the end.

Some of the important terms and ideas covered in this course include sphere, planet, Sun, Moon, satellite, meteor, comet, orbit, rotation, revolution, period, light, shadow, day/night, phase, time, month, hour, image, crater, impact, light, spectrum, surveillance, probe, map, ratio, scale, simulation, model, and graph. Forgotten the difference between revolution and rotation? Don’t worry, that’s exactly the kind of discussion that precedes each investigation.

We have included reference materials in the kit that provide content updates for teachers as well as students. Some of these include

- *The Moon Book*, Kim Long
- *For All Mankind* (DVD)
- *Asteroids—Deadly Impact* (DVD)
- *Hubble's Amazing Universe* (DVD)
- *The Earth's Moon* (map), National Geographic Society
- *Moon Photo* (poster)
- Maps, *Lunar Landing Site Chart*

In addition to these resources, FOSSweb includes an extensive database of resources.
FOSS MIDDLE SCHOOL COMPONENTS

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 and how to teach the subject in a middle school classroom is presented here, along with the resources that will assist the effort. Each middle school Teacher Toolkit has three parts.

Investigations Guide. This three-ring binder contains these chapters.
- Overview
- Materials
- Investigations (ten in this course)

Teacher Resources. This three-ring binder contains these chapters.
- FOSS Middle School Introduction
- Assessment
- Science Notebooks in Middle School
- FOSSweb and Technology
- Science Notebook Masters
- Teacher Masters
- Assessment Masters
- Notebook Answers

The chapters contained in Teacher Resources can also be found on FOSSweb and on a CD included in the Teacher Toolkit.

FOSS Science Resources. This is a copy of the student book of readings, images, and data that are integrated into the instruction.

Equipment Kit
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 be asked to supply small quantities of common classroom items.
**FOSS Science Resources Books**

*FOSS Science Resources: Planetary Science* is a book of original readings developed to accompany this course, along with images and data to analyze during investigations. The readings are referred to as articles in the *Investigations Guide*. Students read the articles in the book as they progress through the course, sometimes during class and sometimes as homework. The articles cover a specific concept, usually after that concept has been introduced in an active investigation.

The articles in *Science Resources* and the discussion questions in the *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.

**FOSSweb and Technology**

The FOSS website opens new horizons for educators, students, and families, in the classroom or at home. Each course has an interactive site where students can find instructional activities, interactive simulations, virtual investigations, and other resources. FOSSweb provides resources for materials management, general teaching tools for FOSS, purchasing links, contact information for the FOSS Program, and technical support. You do not need an account to view this general FOSS Program information. In addition to the general information, FOSSweb provides digital access to PDF versions of the *Teacher Resources* component of the *Teacher Toolkit* and digital-only resources that supplement the print and kit materials.

Additional resources are available to support FOSS teachers. With an educator account, 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 tutorials and online assessments.

**Ongoing Professional Development**

The Lawrence Hall of Science and Delta Education are committed to supporting science educators with unrivaled teacher support, high-quality implementation, and continuous staff-development opportunities and resources. FOSS has a strong network of consultants who have rich and experienced backgrounds in diverse educational settings using FOSS. Find out about professional-development opportunities on FOSSweb.
FOSS INSTRUCTIONAL DESIGN

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

- Active investigation, including multimedia and outdoor experiences
- Recording in science notebooks to answer the focus question
- Reading in FOSS Science Resources
- Assessment to monitor progress and motivate student reflection on learning

In practice, these components are seamlessly integrated into a continuum designed to maximize every student’s opportunity to learn. An instructional sequence may move from one pedagogy to another and back again to ensure adequate coverage of a concept.

FOSS Investigation Organization

Courses are subdivided into investigations (usually ten). Investigations are further subdivided into two to four parts. Each part of each investigation is driven by a focus question. The focus question, presented as the part begins, signals the challenge to be met, mystery to be solved, or principle to be uncovered. The focus question guides students’ inquiry and makes the goal of each part explicit for teachers. Each part concludes with students preparing a written answer to the focus question in their notebooks.

Investigation-specific scientific and historical background information for the teacher is presented in each investigation chapter. The content discussion is divided into sections, each of which relates directly to one of the focus questions. This facilitates finding the exact information you need for each part of the investigation.

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

Teaching notes appear in blue boxes in the sidebar. An arrow points to the place in the lesson where the note applies. These notes constitute a second voice in the curriculum—an educative element. The first (traditional) voice is the message you deliver to students. It supports your work teaching students at all levels, from management to inquiry. The second educative voice is designed to help you understand the science content and pedagogical reasoning at work behind the instructional scene.
The small-group **discussion** icon asks you to pause while students discuss data or construct explanations in their groups. Often a Reporter shares the group’s conclusions with the class.

The **vocabulary** icon indicates where students should record vocabulary in their science notebooks, often just before preparing for a benchmark assessment.

The **recording** icon points out where students should make a science notebook entry. Students can record on prepared notebook sheets or on plain sheets in a bound notebook.

The **engineering** icon indicates opportunities for addressing engineering practices—applying and using scientific knowledge. These opportunities include developing a solution to a problem, constructing and evaluating models, and using systems thinking.

The **reading** icon signals when the class should read a specific article or refer to data in the **FOSS Science Resources**. Some readings are critical to instruction and should take place in class. A reading guide is provided for each such reading.

The **safety** icon alerts you to a potential safety issue. It could relate to the use of a chemical substance, such as salt, requiring protective eyewear, or the possibility of an allergic reaction when students use latex or legumes.

The **assessment** icon appears when there is an opportunity to assess student progress or performance. The assessment methods are usually one of three kinds: observation of students engaged in science practices, review of a notebook entry, or review of students’ work on a prepared assessment tool.

The **technology** icon indicates when to have one or more computers available for accessing FOSSweb to use the multimedia resources. The multimedia is not optional.

The **homework** icon indicates science learning experiences that extend beyond the classroom. Some of the readings are suggested as homework. In that case, you will see two icons by that step.

The **outdoor** icon indicates science learning experiences that extend into the schoolyard.

To help with scheduling, you will see icons for **breakpoints**. Some breakpoints are essential, and others are optional.
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 or challenge from you, or in some cases, from students. What causes day and night? At other times, students are asked to plan a method for investigation. This might start with a teacher demonstration or presentation. Then you challenge students to plan an investigation, such as to find out what a scaled model of an Earth/Moon system would look like. 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.

Multimedia 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 multimedia 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 a summary of their learning as well as questions raised during the activity in their notebooks.

**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-size masters that can be filled in electronically and are suitable for projection are available on FOSSweb.
Reading in 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: Planetary Science book. Students read articles on day length, seasons, impact craters, Moon formation, a survey of the universe, and extraterrestrial planet hunting, as well as historical and biographical material.

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. Additionally, each of these readings 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.

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

Formative assessment in FOSS, called embedded assessment, occurs on a daily basis. You observe action during class or review notebooks after class. 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.

Benchmark assessments are short summative assessments given after one or two investigations. These I-Checks are actually hybrid tools: they provide summative information about students’ achievement, and because they occur soon after teaching an investigation, they can be used diagnostically as well. Reviewing a specific item on an I-Check with the class provides another opportunity for students to clarify their thinking.
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. Within the instructional sequence, you will see the heading What to Look For in red letters. Under that, you will see bullet points telling you specifically what students should know and be able to communicate.

16. Assess progress: response sheet

Distribute a copy of notebook sheet 9, Response Sheet—Investigation 3, to each student. Assign it as homework or have students respond in class. Students should work individually to respond to the items on the back of their sheets or on separate sheets of paper, not directly in their notebooks, so you can collect the sheets when they are finished. Students will self-assess their work on this sheet in Part 2.

What to Look For

- Earth’s orbit around the Sun takes about 365 days and is nearly circular.
- Earth’s axis is tilted 23.5° and always points toward the North Star as Earth revolves around the Sun.
- In summer, the axis is tipped toward the Sun; in winter, the axis is tipped away from the Sun.
- Summer is hotter because days are longer, and light is more concentrated due to less beam spreading.
- The four changes of season are marked by summer solstice (the longest day of the year in the Northern Hemisphere—June 20 or 21), fall equinox (September 22 or 23), winter solstice (December 21 or 22), and spring equinox (March 20 or 21).

If student work is incorrect or incomplete, you know that there has been a breakdown in the learning/communicating process. The assessment system then 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 (survey), at the end of the course (posttest), and after one or two investigations (I-Checks). The benchmark tools are carefully crafted and thoroughly tested assessments.
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. Since the output from the benchmark assessments is descriptive and complex, it can be used for formative as well as summative assessment.

Completely incorporating the assessment system into your teaching practice involves realigning your perception of the interplay between good teaching and good learning, and usually leads to a considerably different social order in the classroom with redefined student-student and teacher-student relationships.
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 Planetary Science 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 the 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. The 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 Planetary Science Course will work in the ideal setting: flat-topped tables where students work with materials in groups of four; theater seating for viewing multimedia (darkened); eight computers networked and linked to the Internet along the far wall; and a library at the back. 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.
- Flat tables or desks appropriate for students to work in groups of four.
- Standard metric measuring tools and classroom supplies, including an electronic balance.
- A whiteboard, blackboard, overhead, or chart paper and marking pens.
- A surface for materials distribution.
- A place to clean and organize equipment.
- A place to store safety goggles that students can get to easily.
- A convenient place to store the kit.
- A computer lab or multiple computers.

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 be sure the multimedia is running smoothly.
- Position your LCD and/or overhead projector(s) where everyone can see comfortably.
• 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 Planetary Science 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, give him or her a chance to spend some time with the materials at a center. Another student might 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.

Allow the student to bring home FOSS Science Resources to read with a family member. Each article has a few review items that the student can respond to verbally or in writing.

And finally, encourage the student to use the resources on FOSSweb at school or at home for the missed class.
Managing Technology

The Planetary Science Course includes a multimedia component. The multimedia is 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 multimedia program to work with the Phases of the Moon simulation, investigate the geometry of the reasons for seasons, or sail simulated ships across round and flat representations of Earth.

The important attribute of the multimedia component is that it is interactive. Students can manipulate variables to see what happens. They can ask the important question What would happen if . . . , and then find out, using the multimedia simulations.

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. Plan on sessions in the computer lab for Investigations 1, 3, 5, 6, 8, and 10.

Option 2: classroom computers. With four to eight computers in the science classroom, you can set up a multitasking environment with half the students working on the multimedia and half engaged in reading or small-group discussions. Then swap roles. This could take one or two periods depending on the activity.

Option 3: learning centers. If you have access to only one computer system, plan to use it with the whole class with a projection system for large-group viewing, followed by opportunities for small groups of students to explore the simulations. Try to organize your classroom for several activities, one of which will be a computer station.

Option 4: 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.
UNIVERSAL DESIGN FOR LEARNING

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.

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 knowledge.


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 30-year tradition of multisensory science education and informed by recent research on UDL. Procedures found effective with students with special needs and students learning English are incorporated into the materials and procedures used with all 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.

**Differentiated Instruction**

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. 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 the vocabulary more explicit through new concrete experiences or through reading to the 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. And for some students, it might be more opportunities for experiencing science outside of the classroom in more natural, outdoor environments.

There are several possible strategies for providing differentiated instruction. The FOSS Program provides tools and strategies so that you know what students are thinking throughout the course. Based on that knowledge, read through the extension activities for experiences that might be appropriate for students who need additional practice with the basic concepts as well as those ready for more advanced projects. Opportunities to extend the investigation are listed at the end of each investigation. Use these ideas to meet the individual needs and interests of your students.
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. Five to eight weeks seems about optimum, so students might work in two groups throughout an 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 **Reporter** makes sure that everyone has recorded information on his or her science notebook sheets. This person reports group data to 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.
SAFETY IN THE CLASSROOM AND OUTDOORS

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. Two posters are included in the kit, Science Safety and Outdoor Safety, 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.

Materials Safety Data Sheets (MSDS) for materials used in the FOSS Program can be found on FOSSweb. If you have questions regarding any MSDS, call Delta Education at 800-258-1302 (Monday–Friday 8 a.m. to 6 p.m. EST).

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 K–8 SCOPE AND SEQUENCE

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