INTRODUCTION

The Motion, Force, and Models Module has four investigations that focus on the physical science concepts of force and motion and provide students with in-depth experiences with scientific and engineering practices. In this module, students will

- Ask questions about systems in the natural and designed worlds, including pendulums, springs, and ramps and balls.
- Design and conduct controlled experiments to find out what variables affect the transfer of energy.
- Use data and logic to construct and communicate reasonable explanations about forces and motion.
- Work with others as scientists and engineers to create conceptual and physical models to explain how something works.
- Plan designs, select materials, construct products, evaluate, and improve ideas to meet specific criteria.
### Module Summary

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<td>What variables might affect the number of cycles a pendulum makes in 15 seconds?</td>
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<td>How does changing the mass, length, or release position of a pendulum affect the</td>
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<td>number of swings the pendulum completes in a unit of time?</td>
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<td>Energy</td>
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<td>Energy</td>
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<td>Inv. 4:</td>
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**Inv. 1: Motion and Variables**

Students are introduced to motion, force, and gravity. They build and observe the motion of a standard pendulum made of string and a penny. Using controlled experiments, students test the variables to see how each variable affects the number of swings the pendulum completes in a given amount of time. Students use the graphs to identify the relationship between the independent and dependent variables in the system.

**Inv. 2: Balls, Ramps, and Energy**

Students conduct structured investigations with steel balls and ramps to discover how the variables of ball size and starting position on the ramp affect the speed of the rolling ball. Using controlled experiments, students test the variables of mass and release position to find out how these variables affect energy transfer; students measure the force involved using spring scales. After gathering data and viewing a momentum animation, students discuss how a concussion is related to the concept of momentum.

**Inv. 3: Springs and Energy**

Students are introduced to a model catapult, called a flipper system. They explore the system to find out how the parts function together. They design controlled experiments to test the effects of variables that change the force applied to an object. After graphing the relationships, students discuss how the amount of bend in the spring affects the amount of potential energy in the system.

**Inv. 4: Models and Design**

Students make multisensory observations of sealed black boxes in an effort to determine what is inside. They develop models and try to reach consensus with other students who investigated the same boxes. Students construct physical models of black boxes in an effort to replicate the behaviors of the original black boxes. To end the module, students use engineering practices to construct a device that meets certain parameters.
### Content Reading Assessment

- Any change of motion requires a force.
- Gravity is the force that pulls objects toward Earth's center.
- A variable is anything you can change that might affect the outcome of an experiment.
- Pendulum experimental data can be graphed to reveal patterns; length determines the number of cycles a pendulum completes in a unit of time.
- Patterns of motion can be observed and can be used to predict motion.

**Science Resources Book**  
“What Causes Change of Motion?”  
“Galileo and Pendulums”

**Embedded Assessment**  
Science notebook entries  
Response sheet  
Scientific practices  
**Benchmark Assessment**  
Survey  
Investigation 1 I-Check

- Objects in motion have energy. The faster an object is moving, the more kinetic energy it has.
- When objects collide, energy can transfer from one object to another, changing their motion.
- Kinetic energy is energy of motion; potential energy is energy of position. For identical objects at rest, the objects at higher heights have more potential energy than the objects at lower heights.
- The total balance of energy in any system is always equal to the total energy transferred into and out of the system.
- Momentum helps maintain an object’s motion.

**Science Resources Book**  
“Bowling”  
“Force and Energy”  
“Potential and Kinetic Energy at Work”  
“Coming to a Stop”  
“Concussion Discussion”

**Media**  
*All about Motion and Balance*

**Embedded Assessment**  
Science notebook entries  
Response sheet  
Scientific practices  
**Benchmark Assessment**  
Investigation 2 I-Check

- Any change of motion requires a force. Each force has a strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give a zero net force (they are balanced).
- The heavier an object is, the greater the force needed to achieve the same change in motion.
- For a given object, a greater force causes a greater change in motion.

**Science Resources Book**  
“Springs in Action”  
“Graphing Data”

**Media**  
*Springs*

**Embedded Assessment**  
Science notebook entry  
Response sheet  
Scientific practices  
**Benchmark Assessment**  
Investigation 3 I-Check

- Models are explanations of objects, events, or systems that cannot be observed directly.
- Models are representations used for communicating and testing.
- Developing a model is an iterative process, which may involve observing, constructing, evaluating, and revising.
- Engineers plan designs, select materials, construct products, evaluate results, and improve ideas.

**Science Resources Book**  
“Scientists and Models”  
“Beachcombing Science”  
“The Path to Invention”  
“Creative Solutions”

**Embedded Assessment**  
Science notebook entry  
Response sheet  
Scientific practices  
**Benchmark Assessment**  
Posttest
FOSS CONCEPTUAL FRAMEWORK

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

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

The FOSS modules are organized into three domains: physical science, earth science, and life science. Each domain is divided into two strands, as shown in the table below for the FOSS Elementary Program. Each strand represents a core idea in science and has a conceptual framework.

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

The sequence in each strand relates to the core ideas described in the 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.

Information about the FOSS learning progression appears in the conceptual framework (page 8), which shows the structure of scientific knowledge taught and assessed in this module, and the content sequence (pages 12–13), a graphic and narrative description that puts this single module into a K–8 strand progression.

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**FOSS Elementary Module Sequences**

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<tr>
<th>PHYSICAL SCIENCE</th>
<th>EARTH SCIENCE</th>
<th>LIFE SCIENCE</th>
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<tbody>
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<td><strong>MATTER</strong></td>
<td><strong>ENERGY AND CHANGE</strong></td>
<td><strong>DYNAMIC ATMOSPHERE</strong></td>
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<td>Mixtures and Solutions</td>
<td>Motion, Force, and Models</td>
<td>Weather on Earth</td>
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<td>Measuring Matter</td>
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<td>Solids and Liquids</td>
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<td>Air and Weather</td>
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**Full Option Science System**
In addition to the science content development, every module provides opportunities for students to engage in and understand the importance of scientific practices, and many modules explore issues related to engineering practices and the use of natural resources.

**Asking questions and defining problems**
- Ask questions about objects, organisms, systems, and events in the natural and human-made world (science).
- Ask questions to define and clarify a problem, determine criteria for solutions, and identify constraints (engineering).

**Planning and carrying out investigations**
- Plan and conduct investigations in the laboratory and in the field to gather appropriate data (describe procedures, determine observations to record, decide which variables to control) or to gather data essential for specifying and testing engineering designs.

**Analyzing and interpreting data**
- Use a range of media (numbers, words, tables, graphs, images, diagrams, equations) to represent and organize observations (data) in order to identify significant features and patterns.

**Developing and using models**
- Use models to help develop explanations, make predictions, and analyze existing systems, and recognize strengths and limitations of proposed solutions to problems.

**Using mathematics and computational thinking**
- Use mathematics and computation to represent physical variables and their relationships and to draw conclusions.

**Constructing explanations and designing solutions**
- Construct logical explanations of phenomena, or propose solutions that incorporate current understanding or a model that represents it and is consistent with available evidence.

**Engaging in argument from evidence**
- Defend explanations, develop evidence based on data, examine one’s own understanding in light of the evidence offered by others, and challenge peers while searching for explanations.

**Obtaining, evaluating, and communicating information**
- Communicate ideas and the results of inquiry—orally and in writing—with tables, diagrams, graphs, and equations—in collaboration with peers.

.motion, force, and models module
BACKGROUND FOR THE CONCEPTUAL FRAMEWORK in Motion, Force, and Models

The Variable Universe

Science is an unending quest for knowledge about the universe and all the objects in it. Sometimes the quest simply looks at the properties and patterns of individual objects; sometimes the quest looks for relationships between the objects. One of the characteristics of science that distinguishes it from other fields of study is the established procedures used by scientists to derive the truest explanations of the events they observe.

One of the most important of these procedures is experimentation. For example, an engineer designing a car for maximum fuel efficiency would have several hundred factors to consider in the overall design. She will have to think about body size and shape, tire size and shape, weight, fuel type, surface, and numerous other details. Everything that might contribute to the overall efficiency of the car is a variable.

After identifying a variable, such as front-end shape, the scientist must systematically investigate how the car behaves with every possible front-end design. Such an investigation is called an experiment. Furthermore, while investigating the effect of front-end shape, all other variables (weight, rear-end design, tires, etc.) must be held the same, or controlled. When she conducts a controlled experiment, the engineer can conclude that any change in efficiency that is observed after an experimental trial can be attributed to the one variable that was changed—in our example, front-end shape.

A car is a fairly complex array of interacting parts. Any association of objects, as complicated as a car, radio, or town, or as simple as a pencil, hammer, or paper cup, can be thought of as a system. A system can be thought of as isolated from the rest of the universe for the sake of study.

With practice, elementary-school students can develop a fairly sophisticated ability to identify variables in a system. Designing experiments that control all of the variables except for one is more difficult. With guidance and experience, however, students will start to develop a functional understanding of this most important concept.
Graphing

Scientists organize the results of their experiments in order to communicate with others as well as to reveal patterns or relationships in the data. Often the organization is some form of a graph. The first graphs that most students make are bar graphs. Bar graphs are useful for making comparisons. Polls (What’s your favorite kind of pie?) and tallies (What color is your pencil?) lend themselves to this kind of organization. At a glance an observer can tell that banana cream is the class’s favorite pie, and that more students use brown pencils. Two-coordinate graphs are useful in exposing relationships between two variables.

There are three levels of abstraction at which data can be displayed. The first level is concrete. The results of an experiment are displayed to show a relationship. Concrete graphing is used in the first investigation when students hang their pendulums on a number line. What they observe is that the longest pendulum hangs on the lowest number, and the shortest pendulum hangs on the highest number. Students in the upper-elementary grades will identify and verbalize the relationship: the longer the pendulum, the fewer the number of swings in a unit of time.

The representational level of abstraction (second level) is the picture graph (pictorial graph). Students draw pendulums exactly as they see them hanging from the number line. The finished pictorial graph looks like reality, and the observer can see the relationship in the picture.

Upper-elementary students are also ready to record their experimental results at the symbolic level of abstraction (third level) on graph paper. At this level nothing looks or feels like the real pendulums—everything is resolved into symbols (numbers). Students plot the points representing the length of each pendulum versus the number of times it swings in 15 seconds. The same relationship is revealed.

In each of these two-coordinate recording systems it is possible to draw a line that connects the pendulum bobs, the drawings of the bobs, or the points on the graph. The curved line that appears is an inverse square relationship. It is not important for elementary-school students to be exposed to this fact, but it is important for them to see that the relationship describes a curved line.
Motion and Force

The world is filled with motion. Some motion happens without human intervention: Earth revolves around the Sun, snowflakes fall to the ground, waves surge across the sea, salmon swim up rivers to fulfill their destinies. Other motions are under our control: clock hands faithfully monitor time, jet planes streak across the sky, baseballs fly over center-field fences, bicycles race in the Tour de France. Both natural and designed motions are part of our perception of the world—there is nothing special about them.

What we take for granted is often worthy of contemplation, in part because it is so commonplace. Familiarity can breed a sense of innate understanding where none really exists. We rarely question what makes things move, often resorting to the popular nonexplanation, “that’s the way the world works.”

Forces make things move or, more accurately, make things change their motion. The two natural forces that affect most of the motion we are aware of are the force of gravity and the electromagnetic force. If a grape slips between your fingers in the backyard, the force of gravity will pull it to the ground. If the same grape happens to fall onto the picnic table, the force of gravity will still pull the grape, but it will not fall to the ground. Why? Because the table is pushing up against the grape with a force exactly equal to the force exerted by gravity pulling the grape down. The force opposing the force of gravity in this example, and most others, is the electromagnetic force, expressed in countless molecular interactions in the matter forming the grape and the table.

**CONCEPTUAL FRAMEWORK**

**Physical Science, Energy and Change: Motion, Force, and Models**

**Motion and Stability: Forces and Interactions**

**Concept A** The motion of an object is determined by the sum of the forces (pushes and pulls) acting on it.

- Any change of motion requires a force. Each force has a strength and a direction.
- An object at rest typically has multiple forces acting on it, but they add to give a zero net force (they are balanced).
- Patterns of motion can be observed; when there are regular patterns of motion, future motions can be predicted.
- The more momentum an object has, the more force it takes to bring it to a stop.

**Concept B** All interactions between objects arise from a few types of forces, primarily gravity and electromagnetism.

- Gravity is the force that pulls objects toward one another. On Earth, the masses are pulled toward Earth’s center.

**Energy Transfer and Conservation**

**Concept A** Energy is a quantitative property (condition) of a system that depends on the motion and interactions of matter and radiation within the system.

- Kinetic energy is energy of motion; potential energy is energy of position. The faster an object is moving, the more kinetic energy it has. Objects at higher heights have more potential energy.

**Concept B** The total change of energy in any system is always equal to the total energy transferred into or out of the system. When two objects interact, each one exerts a force on the other, and these forces can transfer energy.

- When objects collide, energy can transfer from one object to another, thereby changing their motion.
Models and Design

When you ask students to define model, they often give vague answers such as “someone who wears designer clothes,” “a new kind of car,” or possibly “a small plastic boat or plane that looks like a real one.” And, of course, they are right because in common language students talk about so-and-so who chose a career as a model; they hear automobile advertisements for the new models that just arrived on the showroom floor; and if they have the change in their pockets, they might buy a model of the space shuttle to remind them of the opportunities for space exploration that can be theirs if they knuckle down and study science diligently.

To the scientist, a model is something else. We do not understand many things about the universe because we do not have direct access to the objects and systems. How did the solar system come into being, and how long will it endure? What happens to matter when it cools to absolute zero? What happens to an object (or person) when it travels at a velocity in excess of the speed of light? We don’t know the answers to these questions, but that doesn’t mean we don’t have ideas about them. In an effort to answer these questions, people build explanatory models.

Models represent systems (objects and their relationships) and might answer questions. One type of model is a physical model that we can test to see if they meet expectations. Scientists construct scale models of space shuttles and airplanes and subject them to simulated flight conditions in wind tunnels. Because air can be accelerated in wind tunnels to reach speeds equal to those encountered in actual flight, the system is a physical model of an aircraft in flight. By constructing and testing a physical model, aeronautical engineers can investigate design features safely and economically in the laboratory before committing time and resources to construction of a prototype aircraft.

Similarly, geologists try to understand the complexities of Earth’s history by looking at conditions today and generating explanations for how landforms came to be the way they are. One theory of how valleys and canyons formed is that they were eroded by millions of years of flowing water. Geologists can compress time by building a model of Earth’s surface from material less durable than rock and running water over it. The results of such stream-table explorations help geologists understand the processes that might have created the landforms we see today, and they allow the scientists to predict what to expect over the millions of years to come.
When it is not possible to build physical models, because of time, distance, scale, or inaccessibility, a conceptual model can be constructed. Conceptual models are explanatory ideas that are expressed in words and mathematics. They are extremely valuable because they provide a structure of ideas that can engage the thoughtful interest of others—an intellectual point of departure for future investigators. The next investigator might agree, or at least not be able to find any point of disagreement. But when an investigator finds the model wanting, based on fresh observations or new information derived from advanced technology, the model must be revised or abandoned in favor of a better one.

Historically, a series of conceptual models have explained the workings of the solar system. The first comprehensive model was put forth in the second century CE by Ptolemy. His model had Earth in the center of the universe, and it described elaborate rotations of the Sun, Moon, and planets. The model was fairly good at predicting the positions of the bodies, but it needed constant revision because it didn’t explain all observations.

Ptolemy’s model stood for 1400 years until Nicolaus Copernicus proposed a revolutionary conceptual model of the universe—one in which the Sun stood at the center and all of the other bodies moved around it. This was not a popular model, particularly among the theologians of the time, but in a short time the Copernican system was accepted and validated by Kepler and Newton. Today we fly our surrogate eyes, ears, and fingers to the far reaches of the solar system, adding details to the model of the Sun as the center of our solar system that is today accepted as an accurate depiction of reality.
Problem Solving and Technology

This module stresses product-oriented problem solving. This kind of problem solving is employed in both model building and engineering. It calls for divergent, creative thinking and critical interpretation of how to use observations and materials to produce products. In model building, the products are ideas that can be represented in mathematics, words, drawings (conceptual models), or concrete representations (physical models). In engineering, the products are objects, machines, materials, and processes that have uses in everyday life.

Engineering problems are expressed in terms of need: a bridge across the Golden Gate, a material as strong as steel but flexible and half as heavy, a toy car that propels itself for 2 meters. The beauty of these kinds of problems is that they can have many solutions. Ten people might find ten solutions, depending on the resources at hand, a particular insight at a critical moment, or coincidence. Sometimes a solution is obvious and immediate; sometimes a solution comes after a considerable amount of brooding. In the real world, the value of a solution is judged against a myriad criteria; in the classroom, only one: does it fill the need?
Energy and Change Content Sequence

This table shows the five FOSS modules and courses that address the content sequence “energy and change” for grades K–8. Running through the sequence are two progressions—1) motion and stability: forces and interactions, and 2) energy transfer and conservation. The supporting elements in each module (somewhat abbreviated) are listed. The elements for the Motion, Force, and Models Module are expanded to show how they fit into the sequence.

<table>
<thead>
<tr>
<th>Module or course</th>
<th>Motion and Stability: Forces and Interactions</th>
<th>Energy Transfer and Conservation</th>
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</thead>
<tbody>
<tr>
<td><strong>Electronics</strong></td>
<td>• A circuit is a pathway through which electric current (energy) can transfer to produce light and other effects.</td>
<td>• Energy can be moved from place to place by electric currents.</td>
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<tr>
<td></td>
<td>• Voltage (electromotive force) is the push that moves electric current through a circuit.</td>
<td>• Current (electric energy) is the amount of charge moving past a point in a conductor in a unit of time.</td>
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<td></td>
<td>• Resistance is a property of materials that impedes the flow of electric current.</td>
<td>• The sum of the voltage drops in a circuit is equal to the voltage available at the source.</td>
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<tr>
<td></td>
<td>• There is a relationship (Ohm’s law) between resistance, voltage, and electric current in a circuit.</td>
<td>• Voltage drop is proportional to resistance.</td>
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<tr>
<td>Force and Motion</td>
<td>• A net force is the sum of the forces acting on a mass; a net force applied to a mass results in acceleration of the mass.</td>
<td>• Resistances in series add; resistances in parallel add inversely.</td>
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<td></td>
<td>• Gravity is a force pulling two masses toward each other; the strength of the force depends on the objects’ masses.</td>
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<td></td>
<td>• The heavier the object, the greater the force needed to achieve the same change in motion.</td>
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<td><strong>Motion, Force, and Models</strong></td>
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</tr>
<tr>
<td>Energy and Electromagnetism</td>
<td>• Magnets interact with each other and with materials that contain iron.</td>
<td>• Energy is present whenever there is motion, electric current, sound, light, or heat.</td>
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<td></td>
<td>• Like poles of magnets repel each other; opposite poles attract. The magnetic force declines as the distance between the magnets increases.</td>
<td>• Electricity (electric current) transfers energy that can produce heat, light, sound, and motion. Electricity can be produced from a variety of sources.</td>
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<tr>
<td></td>
<td>• Conductors are materials through which electric current can flow; all metals are conductors.</td>
<td>• A circuit is a system that includes a complete pathway through which electric current flows from a source of energy to its components.</td>
</tr>
<tr>
<td>Balance and Motion</td>
<td>• Objects can be balanced in many ways; counterweights can balance an object.</td>
<td>• Energy can be generated by burning fossil fuels or harnessing renewable energy.</td>
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<td></td>
<td>• Pushing or pulling on an object can change the speed or direction of its motion (rolling, rotation, vibration) and can start or stop it.</td>
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<td></td>
<td>• Magnetic force acts at a distance to make objects move by pushing or pulling.</td>
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<td></td>
<td>• A bigger push or pull makes things go faster.</td>
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<td>• Sound comes from vibrating objects.</td>
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<td></td>
<td>• Larger objects vibrate slowly and produce low-pitched sounds; smaller objects vibrate quickly and produce high-pitched sounds.</td>
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• Any change of motion requires a force. Each force has a strength and a direction.
• Gravity is the force that pulls objects toward Earth’s center.
• Patterns of motion can be observed; when there are regular patterns of motion, motion can be predicted.
• An object at rest typically has multiple forces acting on it, but they add to give a zero net force (they are balanced).

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<td>• When objects collide, energy can transfer from one object to another, thereby changing their motion; a larger force causes a larger change in motion.</td>
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<td>• Kinetic energy is energy of motion; potential energy is energy of position. For identical objects at rest, the objects at higher heights have more potential energy than objects at lower heights.</td>
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The Motion, Force, and Models Module aligns with the NRC Framework. The module addresses these 3–5 grade band endpoints described for core ideas from the national framework for physical science and for engineering, technology, and the application of science.

Physical Sciences

Core idea PS2: Motion and Stability: Forces and Interactions—How can one explain and predict interactions between objects and within systems of objects?

- **PS2.A**: How can one predict an object’s continued motion, changes in motion, or stability? [Each force acts on one particular object and has both a strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. The patterns of an object’s motion in various situations can be observed and measured; when past motion exhibits a regular pattern, future motion can be predicted from it.]

- **PS2.B**: What underlying forces explain the variety of interactions observed? [Objects in contact exert forces on each other (friction, elastic pushes and pulls.) Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact—for example, magnets push or pull at a distance. The sizes of the forces in each situation depend on the properties of the objects and their distances apart, and for forces between two magnets, on their orientation relative to each other. The gravitational force of Earth acting on an object near Earth’s surface pulls that object toward the planet’s center.]

- **PS2.C**: Why are some physical systems more stable than others? [A system can change as it moves in one direction (e.g., a ball rolling down a hill), shifts back and forth (e.g., a swinging pendulum), or goes through cyclical patterns (e.g., day and night). Examining how the forces on and within the system change as it moves can help to explain the system’s patterns of change.]
Core idea PS3: Energy—How is energy transferred and conserved?

- **PS3.A:** What is energy? [The faster a given object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)]

- **PS3.B:** What is meant by conservation of energy? How is energy transferred between objects or systems? [Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.]

- **PS3.C:** How are forces related to energy? [When objects collide, the contact forces transfer energy so as to change the objects’ motions.]
Engineering, Technology, and Applications of Science

Core idea ETS1: Engineering Design—How do engineers solve problems?

- **ETS1.A: What is a design for?** What are the criteria and constraints of a successful solution? [Possible solutions to a problem are limited by available materials and resources (constraints). The success of a design solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.]

- **ETS1.B: What is the process for developing potential design solutions?** [Research on a problem should be carried out—for example, through Internet searches, market research, or field observations—before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. Testing a solution involves investigating how well it performs under a range of likely conditions. Tests are often designed to identify failure point or difficulties, which suggest the elements of the design that need to be improved. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

There are many types of models, ranging from simple physical models to computer models. They can be used to investigate how a design might work, communicate the design to others, and compare different designs.]
Core idea ETS2: Links among Engineering, Technology, Science, and Society—How are engineering, technology, science, and society interconnected?

- **ETS2.A**: What are the relationships among science, engineering, and technology? [Tools and instruments (e.g., rulers, balances, thermometers, graduated cylinders, telescopes, microscopes) are used in scientific exploration to gather data and help answer questions about the natural world. Engineering design can develop and improve such technologies. Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. Knowledge of relevant scientific concepts and research findings is important in engineering.]

- **ETS2.B**: How do science, engineering, and the technologies that result from them affect the ways in which people live? How do they affect the natural world? [Over time, people’s needs and wants change, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), to decrease known risks (e.g., seatbelts in cars), and to meet societal demands (e.g., cell phones). When new technologies become available, they can bring about changes in the way people live and interact with one another.]
FOSS 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 module, how to teach the subject, and the resources that will assist the effort are presented here. Each toolkit has three parts.

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

- Overview
- Materials
- Investigations (four in this module)
- Assessment

*Teacher Resources.* This collection of resources contains these chapters.

- FOSS Introduction
- Science Notebooks in Grades 3–6
- Science-Centered Language Development
- Taking FOSS Outdoors
- FOSSweb and Technology
- Science Notebook Masters
- Teacher Masters
- Assessment Masters

The chapters contained in the *Teacher Resources* and the Spanish duplication masters can also be found on FOSSweb (www.FOSSweb.com) and on CDs included in the *Teacher Toolkit*.

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

Equipment Kit

The FOSS Program provides the materials needed for the investigations, including metric measuring tools, 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 two uses before you need to resupply. Teachers might be asked to supply small quantities of common classroom items.
FOSS Components

FOSS Science Resources Books

FOSS Science Resources: Motion, Force, and Models is a book of original readings developed to accompany this module. The readings are referred to as articles in the Investigations Guide. Students read the articles in the book as they progress through the module. 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 provided 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 module has an interactive site where students and families can find instructional activities, interactive simulations and virtual investigations, and other additional resources. FOSSweb provides resources for materials management, general teaching tools for FOSS, purchasing links, contact information for the FOSS Project, 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 modules 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.

NOTE
To access all the teacher resources and to set up customized pages for using FOSS, log in to FOSSweb through an educator account.
FOSS INSTRUCTIONAL DESIGN

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

- Active investigation, including 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 might move from one pedagogy to another and back again to ensure adequate coverage of a concept.

FOSS Investigation Organization

Modules are subdivided into investigations (four in this module). Investigations are further subdivided into 3–4 parts. Each part of each investigation is driven by a focus question. The focus question, usually 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’ actions and thinking and makes the learning goal of each part explicit for teachers. Each part concludes with students recording an answer to the focus question in their notebooks.

Investigation-specific scientific 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 section ends with information about teaching and learning and a conceptual-flow diagram for the content.

The Getting Ready and Guiding the Investigation sections have several features that are flagged or presented 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.

Teaching notes appear in blue boxes in the sidebars. These notes comprise 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, shared as a teaching note, is designed to help you understand the science content and pedagogical rationale at work behind the instructional scene.
The safety icon alerts you to a potential safety issue. It could relate to the use of a chemical substance, such as salt, requiring safety goggles, or the possibility of a student allergic reaction when students use latex, legumes, or wheat.

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 new-word icon alerts you to a new vocabulary word or phrase that should be introduced thoughtfully. The new vocabulary should also be entered onto the word wall (or pocket chart). A complete list of the scientific vocabulary used in each investigation appears in the sidebar on the last page of the Background for the Teacher section.

The vocabulary icon indicates where students should review recently introduced vocabulary, often just before they will be answering the focus question or preparing for benchmark assessment.

The recording icon points out where students should make a science-notebook entry. Students record on prepared notebook sheets or, increasingly, on pages in their science notebooks.

The reading icon signals when the class should read a specific article in the FOSS Science Resources book, preferably during a reading period.

The assessment icon appears when there is an opportunity to assess student progress by using embedded or benchmark assessments. Some of the embedded-assessment methods for grades 3–6 include observation of students engaged in scientific practices, review of a notebook entry, and response sheets.

The outdoor icon signals when to move the science learning experience into the schoolyard. It also helps you plan for selecting and preparing an outdoor site for a student activity.

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 EL note in the sidebar provides a specific strategy to use to assist English learners in developing science concepts. A discussion of strategies is in the Science-Centered Language Development chapter.

To help with pacing, 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. How does changing the length of a pendulum change the number of swings? 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 how much force can a rolling ball apply during a collision. 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, observe systems and interactions, and 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.

**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 science notebooks. Data recording is the first of several kinds of student writing.

Students then organize data so 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 science notebooks a summary of their learning as well as questions raised during the activity.

**Science Notebooks**

Research and best practice have led FOSS 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. The science-notebook entries stand as credible and useful expressions of learning. The artifacts in the notebooks form one of the core elements of the assessment system.

You will find the duplication masters for grades 1–6 presented in notebook format. They are reduced in size (two copies to a standard sheet) for placement (glue or tape) into a bound composition book. Full-size duplication masters are also available on FOSSweb. Student work is entered partly in spaces provided on the notebook sheets and partly on adjacent blank sheets.
Reading in FOSS Science Resources

The FOSS Science Resources books emphasize expository articles and biographical sketches. FOSS suggests that the reading be completed during language-arts time. When language-arts skills and methods are embedded in content material that relates to the authentic experience students have had during the FOSS active learning sessions, students are interested, and they get more meaning from the text material.

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 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 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 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.
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 module (Survey) and at the end of the module (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 or not a student knows a piece of science content. They 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.

22. Assess progress: notebook entry

Have students hand in their notebooks open to the page on which they answered the focus question. Review students’ notebooks after class and check their understanding of variables they could investigate to further their understanding of pendulums. Record your notes on a copy of the Embedded Assessment Notes.

What to Look For

- Students write that the mass of the bob (number of pennies), the length of the pendulum string, and the release position are the variables they could change.
- Students might indicate other variables, such as how to attach the pennies or type of string, or providing an additional push.
Taking FOSS Outdoors

FOSS throws open the classroom door and proclaims the entire school campus to be the science classroom. The true value of science knowledge is its usefulness in the real world and not just in the classroom. Taking regular excursions into the immediate outdoor environment has many benefits. First of all, it provides opportunities for students to apply things they learned in the classroom to novel situations. When students are able to transfer knowledge of scientific principles to natural systems, they experience a sense of accomplishment.

In addition to transfer and application, students can learn things outdoors that they are not able to learn indoors. The most important object of inquiry outdoors is the outdoors itself. To today’s youth, the outdoors is something to pass through as quickly as possible to get to the next human-managed place. For many, engagement with the outdoors and natural systems must be intentional, at least at first. With repeated visits to familiar outdoor learning environments, students might first develop comfort in the outdoors, and then a desire to embrace and understand natural systems.

The last part of most investigations is an outdoor experience. Venturing out will require courage the first time or two you mount an outdoor expedition. It will confuse students as they struggle to find the right behavior that is a compromise between classroom rigor and diligence and the freedom of recreation. With persistence, you will reap rewards. You will be pleased to see students’ comportment develop into proper field-study habits, and you might be amazed by the transformation of students with behavior issues in the classroom who become your insightful observers and leaders in the schoolyard environment.

Teaching outdoors is the same as teaching indoors—except for the space. You need to manage the same four core elements of teaching: time, space, materials, and students. 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 the Teacher Resources.

FOSS is very enthusiastic about this dimension of the program and looks forward to hearing about your experience using the schoolyard as a logical extension of your classroom.
Science-Centered Language Development

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 chapter in Teacher Resources, we explore the intersection of science and language and the implications for effective science teaching and language development. We identify best practices in language-arts instruction that support science learning and examine how learning science content and engaging in scientific practices support 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. For students, language development is intimately involved in their learning about the natural world. Science provides a real and engaging context for developing literacy, and language-arts skills and strategies support conceptual development and scientific practices. For example, 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. Students’ use of language improves when they discuss (speak and listen, as in the Wrap-Up/Warm-Up activities), write, and read about the concepts explored in each investigation.

There are many ways to integrate language into science investigations. 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. The last section covers language-development strategies that are specifically for English learners.
FOSSWEB AND TECHNOLOGY

FOSS is committed to providing a rich, accessible technology experience for all FOSS users. FOSSweb is the Internet access to FOSS digital resources. It provides enrichment for students and support for teachers, administrators, and families who are actively involved in implementing and enjoying FOSS materials. Here are brief descriptions of selected resources to help you get started with FOSS technology.

Technology to Engage Students at School and at Home

**Multimedia activities.** The multimedia simulations and activities were designed to support students’ learning. They include virtual investigations and student tutorials that you can use to support students who have difficulties with the materials or who have been absent.

**FOSS Science Resources.** The student reading book is available as an audio book on FOSSweb, accessible at school or at home. In addition, as premium content, **FOSS Science Resources** is available as an eBook. The eBook supports a range of font sizes and can be projected for guided reading with the whole class as needed.

**Home/school connection.** Each module includes a letter to families, providing an overview of the goals and objectives of the module. Most investigations have a home/school activity providing science experiences to connect the classroom experiences with students’ lives outside of school. These connections are available in print in the **Teacher Resources** and on FOSSweb.

**Student media library.** A variety of media enhance students’ learning. Formats include photos, videos, an audio version of each student book, and frequently asked science questions. These resources are also available to students when they log in with a student account.

**Recommended books and websites.** FOSS has reviewed print books and digital resources that are appropriate for students and prepared a list of these media resources.

**Class pages.** Teachers with a FOSSweb account can easily set up class pages with notes and assignments for each class. Students and families can then access this class information online.
Technology to Support Teachers

Teacher-preparation video. The video presents information to help you prepare for a module, including detailed investigation information, equipment setup and use, safety, and what students do and learn through each part of the investigation.

Science-notebook masters and teacher masters. All notebook masters and teacher masters used in the modules are available digitally on FOSSweb for downloading and for projection during class. These sheets are available in English and Spanish.

Assessment masters. The benchmark assessment masters for grades 1–6 (I-Checks) are available in English and Spanish.

Focus questions. The focus questions for each investigation are formatted for classroom projection and for printing onto labels that students can glue into their science notebooks.

Equipment photo cards. The cards provide labeled photos of equipment supplied in each FOSS kit.

Materials Safety Data Sheets (MSDS). These sheets have information from materials manufacturers on handling and disposal of materials.

Teacher Resources chapters. FOSSweb provides PDF files of all chapters from the Teacher Resources.
  • FOSS Introduction
  • Science Notebooks
  • Science-Centered Language Development
  • Taking FOSS Outdoors
  • FOSSweb and Technology

Streaming video. Some video clips are part of the instruction in the investigation, and others extend concepts presented in a module.

Resources by investigation. This digital listing provides online links to notebook sheets, assessment and teacher masters, and multimedia for each investigation of a module for projection in the classroom.

Interactive whiteboard resources. You can use these slide shows and other resources with an interactive whiteboard.

Investigations eGuide. The eGuide is the complete Investigations Guide component of the Teacher Toolkit in an electronic web-based format, allowing access from any Internet-enabled computer.
Module summary. The summary describes each investigation in a module, including major concepts developed.

Module updates. These are important updates related to the teacher materials, student equipment, and safety guidelines.

Module teaching notes. These notes include teaching suggestions and enhancements to the module, sent in by experienced FOSS users.

FOSSmap and online assessments. A computerized assessment program, called FOSSmap, provides a system for students to take assessments online, and for you to review those assessments online and to assign tutorial sessions for individual students based on assessment performance. You generate a password for students to access and take the assessments online.

Most assessment items are multiple-choice, multiple-answer, or short-answer questions, but for one or two questions, students must write sentences. These open-response questions can be answered either online or using paper and pencil.

After students have completed a benchmark assessment, FOSSmap automatically codes (scores) the multiple-choice, multiple-answer, and short-answer questions. You will need to check students’ responses for short-answer questions to make sure that the questions have been coded correctly. Students’ open-response questions are systematically displayed for coding. If students have taken any part of the test via paper and pencil, you will need to enter students’ answers on the computer for multiple-choice and multiple-answer questions (the computer automatically codes the answers), and to code the short-answer and open-response questions.

Once the codes are in the FOSSmap program, you can generate and display several reports.

The Code-Frequency Report is a bar graph showing how many students received each code. This graph makes it easy to see which items might need further instruction.

In the Class-by-Item Report, each item is presented in a text format that indicates a percentage and provides names of students who selected each answer. It also describes what a code means in terms of what students know or need to work on.
The *Class-by-Level Report* describes four levels of achievement. It lists class percentages and students who achieved each level.

The *Class-Frequency Report* has bar graphs indicating how many students achieved each level. The survey and posttest are shown on the same page for easy comparison. I-Checks appear on separate pages.

The *Student-by-Item Report* is available for each student. It provides information about the highest code possible, the code the student received, and a note describing what the student knows or what he or she needs to work on. This report also suggests online tutorials to assign to students who need additional help.

The *Student Assessment Summary* bar graph indicates the level achieved by individual students on all the assessments taken up to any point in the module. This graph makes it easy to compare achievement on the survey and posttest as well as on each I-Check.

**Tutorials.** You can assign online tutorials to individual students, based on how each student answers questions on the I-Checks and posttest. The *Student-by-Item Report*, generated by FOSSmap, indicates the tutorials specifically targeted to help individual students refine their understandings. Tutorials are an excellent tool for differentiating instruction and are available to students at any time on FOSSweb.
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 who are learning English are incorporated into the materials and strategies 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. Strategies for helping all primary 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.

**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 vocabulary more explicit through new concrete experiences or through reading to students. For some students, it might 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.

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 module. 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. Interdisciplinary extensions 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 might 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 upper-elementary grades, 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. Six to nine weeks seems about optimum, so students might stay together throughout an entire module.

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 them in place of those 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.

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

There is a set of two or three virtual investigations for each FOSS module for grades 3–6. Students who have been absent from certain investigations can access these simulations online through FOSSweb. The virtual investigations require students to record data and answer concluding questions in their science notebooks. Sometimes the notebook sheet that was used in the classroom investigation is also used for the virtual investigation.
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 you do is consistent with those guidelines. Two posters are included in the kit: Science Safety for classroom use and Outdoor Safety for outdoor activities.

Look for the safety icon in the Getting Ready and Guiding the Investigation sections that will alert you to safety considerations throughout the module.

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 1-800-258-1302 (Monday–Friday, 8 a.m.–6 p.m. EST).

Science Safety in the Classroom

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

1. Listen carefully to your teacher’s instructions. Follow all directions. Ask questions if you don’t know what to do.
2. Tell your teacher if you have any allergies.
3. Never put any materials in your mouth. Do not taste anything unless your teacher tells you to do so.
4. Never smell any unknown material. If your teacher tells you to smell something, wave your hand over the material to bring the smell toward your nose.
5. Do not touch your face, mouth, eyes, or nose while working with chemicals, plants, or animals.
6. Always protect your eyes. Wear safety goggles when necessary.
7. Tell your teacher if you wear contact lenses.
8. Always wash your hands with soap and warm water after handling chemicals, plants, or animals.
9. Never mix any chemicals unless your teacher tells you to do so.
10. Report all spills, accidents, and injuries to your teacher.
11. Treat animals with respect, caution, and consideration.
12. Clean up your work space after each investigation.
13. Act responsibly during all science activities.
SCHEDULING THE MODULE

The Getting Ready section for each part of an investigation helps you prepare. It provides information on scheduling the activities and introduces the tools and techniques used in the activity. Be prepared—read the Getting Ready section thoroughly.

Below is a suggested teaching schedule for the module. The investigations are numbered and should be taught in order, as the concepts build upon each other from investigation to investigation. We suggest that a minimum of 10 weeks be devoted to this module. Take your time, and explore the subject thoroughly.

**Active-investigation (A)** sessions include hands-on work with physical systems and tools, active thinking about experiences, small-group discussion, writing in science notebooks, and learning new vocabulary in context.

During **Wrap-Up/Warm-Up (W)** sessions, students share notebook entries and discuss their answers to the focus questions.

**Reading (R)** sessions involve reading FOSS Science Resources articles.

**I-Checks** are short summative assessments at the end of each investigation. The next day, after you have coded the assessments, students self-assess their written responses on a few critical items to reflect on and improve their understanding.

<table>
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<tr>
<th>Week</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
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<td>A/W</td>
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## FOSS K–8 SCOPE AND SEQUENCE

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<th>Grade</th>
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<th>Life Science</th>
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<td>Electronics</td>
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<td>Human Brain and Senses</td>
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<td>Earth History</td>
<td>Populations and Ecosystems</td>
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<td>Force and Motion</td>
<td>Weather and Water</td>
<td>Diversity of Life</td>
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<td>Weather on Earth</td>
<td>Living Systems</td>
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<td>Environments</td>
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<td>Water</td>
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<td>Air and Weather</td>
<td>Insects and Plants</td>
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