INTRODUCTION TO PERFORMANCE EXPECTATIONS

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

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

This chapter also provides details about how this FOSS module fits into the matrix of the FOSS Program (page 41). Each FOSS module K–5 and middle school course 6–8 has a functional role in the FOSS conceptual frameworks that were developed based on a decade of research on science education and the influence of A Framework for K–12 Science Education (2012) and Next Generation Science Standards (NGSS, 2013).

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

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

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

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

The Mixtures and Solutions Module connects with the NRC Framework 3–5 grade band and the NGSS performance expectations for grade 5. The module focuses on core ideas for Physical sciences.

Physical Sciences

Framework core idea PS1: Matter and its interactions—How can one explain the structure, properties, and interactions of matter?

• PS1.A: Structures and properties of matter

How do particles combine to form the variety of matter one observes? [Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in condensation, fog, and, by extension, also in clouds or the contrails of a jet. The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (e.g., sugar in solution, evaporation in a closed container). Measurement of a variety of properties (e.g., hardness, reflectivity) can be used to identify particular materials.]

• PS1.B: Chemical reactions

How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them? [When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Assessment Boundary: Mass and weight are not distinguished at this grade level).]
The following NGSS Performance Expectations for PS1 is derived from the Framework disciplinary core ideas above.

• 5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen. [Clarification Statement: Examples of evidence could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.] [Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.]

• 5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. [Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.] [Assessment Boundary: Assessment does not include distinguishing mass and weight.]

• 5-PS1-3. Make observations and measurements to identify materials based on their properties. [Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [Assessment Boundary: Assessment does not include density or distinguishing mass and weight.]

• 5-PS1-4. Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

REFERENCES

DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has two core ideas in engineering, technology, and applications of science.

ETS1: Engineering design

ETS2: Links among engineering, technology, science, and society

NOTE: Only one of these core ideas, ETS1, is represented in the NGSS performance expectations for grade 5.

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC Framework 3–5 grade band to keep the core ideas in a rich and useful context.

The performance expectations related to each core idea are taken from the NGSS for grades 3–5.

Engineering, Technology, and Applications of Science Framework core idea ETS1: Engineering design—How do engineers solve problems?

• ETS1.A: Defining and delimiting an engineering problem
  What is a design for? What are the criteria and constraints of a successful solution? [Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed 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: Developing possible solutions
  What is the process for developing potential design solutions? [Research on a problem should be carried out 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 points or difficulties, which suggest the elements of a design that need to be improved. At whatever stage, communication with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.]

• ETS1.C: Optimizing the design solution
  How can the various proposed design solutions be compared and improved? [Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.]
The following NGSS Grades 3–5 Performance Expectations for ETS1 are derived from the Framework disciplinary core ideas on the previous page.

- **3-5-ETS1-1.** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

- **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

- **3-5-ETS1-3.** Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
SCIENCE AND ENGINEERING PRACTICES

A Framework for K–12 Science Education (National Research Council, 2012) describes eight science and engineering practices as essential elements of a K–12 science and engineering curriculum. All eight practices are incorporated into the learning experiences in the Mixtures and Solutions Module.

The learning progression for this dimension of the framework is addressed in Next Generation Science Standards (National Academies Press, 2013), volume 2, appendix F. Elements of the learning progression for practices recommended for grade 5 as described in the performance expectations appear in bullets below each practice.

Science and Engineering Practices Addressed

1. Asking questions and defining problems
   - Ask questions that can be investigated based on patterns such as cause-and-effect relationships.
   - Define a simple design problem that can be solved through the development of a new or improved object or tool.

2. Developing and using models
   - Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.
   - Develop and/or use models to describe phenomena.
   - Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.
   - Use a model to test cause-and-effect relationships or interactions concerning the functioning of a natural system.

3. Planning and carrying out investigations
   - Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
   - Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
   - Make predictions about what would happen if a variable changes.

4. Analyzing and interpreting data
   - Represent data in tables and/or various graphical displays to reveal patterns that indicate relationships.
   - Analyze and interpret data to make sense of phenomena using logical reasoning.
   - Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
   - Use data to evaluate claims about cause and effect.

5. Using mathematics and computational thinking
   - Describe, measure, estimate, and/or graph quantities such as weight to address scientific and engineering questions.
6. **Constructing explanations and designing solutions**

   • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
   • Identify the evidence that supports particular points in an explanation.
   • Apply scientific ideas to solve design problems.
   • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

7. **Engaging in argument from evidence**

   • Construct an argument with evidence, data, and/or models.
   • Use data to evaluate claims about cause and effect.

8. **Obtaining, evaluating, and communicating information**

   • Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.
   • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
   • Communicate scientific and/or technical information orally and/or in written formats, including various forms of media, such as tables, diagrams, and charts.
Crosscutting Concepts Addressed

Patterns
- Similarities and differences in patterns can be used to sort and classify natural phenomena. Patterns of change can be used to make predictions and as evidence to support an explanation.

Cause and effect
- Cause-and-effect relationships are routinely identified and used to explain change.

Scale, proportion, and quantity
- Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

Systems and system models
- A system can be described in terms of its components and their interactions.

Energy and matter
- Matter is made of particles.
- Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. That is what is meant by conservation of matter. Matter is transported into, out of, and within systems.

Connections: Understandings about the Nature of Science

Scientific investigations use a variety of methods.
- Scientific methods are determined by questions. Scientific investigations use a variety of methods, tools, and techniques.

Scientific knowledge is based on empirical evidence.
- Science findings are based on recognizing patterns.
- Scientists use tools and technologies to make accurate measurements and observations.
**Introduction to Performance Expectations**

**Scientific knowledge is open to revision in light of new evidence.**
- Scientific knowledge can change based on new evidence.

**Science is a way of knowing.**
- Science is both a body of knowledge and processes that add new knowledge. Science is a way of knowing that is used by many people.

**Science models, laws, mechanisms, and theories explain natural phenomena.**
- Scientific theories are based on a body of evidence and many tests. Scientific explanations describe the mechanisms for natural events.

**Science is a human endeavor.**
- Men and women from all cultures and backgrounds choose careers as scientists and engineers. Most scientists and engineers work in teams. Science affects everyday life. Creativity and imagination are important to science.

**Science addresses questions about the natural and material worlds.**
- Scientific findings are limited to what can be answered with empirical evidence.

**Connections to Engineering, Technology, and Applications of Science**
- **Influence of science, engineering, and technology on society and the natural world.** Engineers improve existing technologies or develop new ones. Over time, people’s needs and wants change, as do their demands for new and improved technologies. When new technologies become available, they can bring about changes in the way people live and interact with one another.

- **Interdependence of science, engineering, and technology.** Science and technology support each other. Knowledge of relevant scientific concepts and research findings is important in engineering. Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies.

**CONNECTIONS**
See volume 2, appendix H and appendix J, in the NGSS for more on these connections.

For details on learning connections to Common Core State Standards English Language Arts and Math, see the chapters FOSS and Common Core ELA—Grade 5 and FOSS and Common Core Math—Grade 5 in *Teacher Resources*. 
FOSS CONCEPTUAL FRAMEWORK

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

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

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

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

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

The sequence in each strand relates to the core ideas described in the NRC Framework. Modules at the bottom of the table form the foundation in the primary grades. The core ideas develop in complexity as you proceed up the columns.
Information about the FOSS learning progression appears in the conceptual frameworks (page 43 and 47), which shows the structure of scientific knowledge taught and assessed in this module, and the content sequence (pages 48-49), a graphic and narrative description that puts this single module into a K–8 strand progression.

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

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

The Basis of It All

Everything in the known universe can be put into one of two categories: matter or energy. Matter is the material of the universe, and energy is the drive that makes things happen. Chemistry is the study of the properties, relationships, and interactions of matter, and the energy changes that result from chemical interactions.

All the matter on Earth is made up of 90 naturally occurring chemical elements. Some elements are familiar substances, such as sulfur, silver, hydrogen, and iron; some are rare, such as erbium, gadolinium, lutetium, and rhenium. Elements combine in various ways to form the great variety of substances that make up the universe. The elements themselves are made up of atoms, which are the smallest particles into which an element can be divided and yet retain its characteristics.

Atoms are not usually found in pure (element) form, but rather are attached to other atoms in stable associations of molecules. A molecule that contains atoms of more than one element is called a compound. Compounds can be relatively simple, composed of two- or three-atom units, such as water (two hydrogen atoms and one oxygen atom) and carbon dioxide (one carbon atom and two oxygen atoms), or they can be complex, composed of scores of atoms, such as hemoglobin and chlorophyll. Even though thousands of different kinds of molecules have been discovered in nature or manufactured in chemistry labs (dyes, flavors, plastics, lubricants, acids, fuels, on and on), a seemingly infinite array of new molecules could yet be discovered.

On our planet, matter commonly appears in only three natural states—solid, liquid, and gas. A piece of gold is a solid, water is a well-known liquid, and the oxygen in the air we breathe is a gas. Often when a solid is heated, it melts and becomes a liquid. If heating continues, the liquid might vaporize and become a gas. When water cools enough, it turns into a solid called ice. When water warms, it evaporates, turning into a gas called water vapor. These changes of state are interesting to the chemist because they often take up or give off energy.
CONCEPTUAL FRAMEWORK
Physical Sciences, Matter:
Mixtures and Solutions

Matter Has Structure
Concept A  Matter exists in three states (solid, liquid, and gas), which have observable properties.
  • Matter is made of particles too small to be seen.
  • Solids have a definite shape and volume; liquids have a definite volume, but take the shape of their containers; gases have neither a definite volume or shape.

Concept B  Matter has physical properties that can be observed and quantified.
  • Materials can be identified based on their properties, e.g., solubility, crystal shape after evaporation.
  • Concentration is the amount of dissolved solid material per unit volume of water.
  • Solubility is the property that indicates how readily a solute dissolves in a solvent. Saturation occurs when as much solid material as possible has dissolved.
  • Density is mass per unit volume. The greater the concentration of a solution, the greater its density.

Matter Interacts
Concept A  Mass of material is conserved.
  • Regardless of the type of change that occurs when heating, cooling, or mixing substances, the total mass (weight) of matter is conserved.

Concept B  Change of temperature can produce changes in physical state.
  • Melting, freezing, evaporating, and condensing are changes of state.

Concept C  During physical interactions, substances form mixtures in which the interacting substances retain their original properties.
  • A mixture is two or more materials intermingled. Mixtures can be separated with different tools.
  • An aqueous solution is a mixture in which a solute dissolves in a solvent to make a clear liquid.

Concept D  During chemical interactions, starting substances (reactants) change into new substances (products).
  • Formation of a gas or precipitate is evidence of a chemical reaction.
Putting Different Kinds of Matter Together

When two or more kinds of matter are combined, the result is a mixture. Simple mixtures include sand and water, oil and vinegar, nuts and bolts, coleslaw, rocky road ice cream, and trail mix. Mixtures can be made with any combination of gases, liquids, and solids. Once assembled, mixtures can be separated using physical means, such as hand separation, screening, filtering, and evaporation. The components of a mixture are not changed by mixing with other materials. The resulting mass of a mixture is the sum of the masses of the components.

Sometimes when two (or more) materials are mixed, a different kind of mixture results. For example, when salt and water are mixed, the solid salt seems to disappear in the water. This process is called dissolving; we say that the salt dissolved in the water. This mixture is a solution. When a solid dissolves in a liquid, the liquid is the solvent, and the solid material is the solute. All mixtures can be separated by physical means. A solution of a liquid and a solid can be separated by evaporating the liquid (the solvent). If a solution is heated so that the solvent changes phase from liquid to gas, the gas will escape into the air, leaving the salt behind.

Most solutions are made by mixing a solid and a liquid, but mixtures of matter in other states can also form solutions. Air is a solution made of several gases, including nitrogen, oxygen, helium, carbon dioxide, and small amounts of many other gases. Brass is a solid solution made from zinc and copper. Carbonated water is a solution of carbon dioxide gas dissolved in liquid water. In fact, any mixture in which the particles are distributed uniformly throughout, and no particle is larger than 5 nanometers (nm), is a solution. A nanometer is one-billionth of a meter, so 5 nm is a particle of tiny dimensions.

Investigating Solutions

Solid/liquid solutions can differ from one another in two significant ways. First, they can be made from different materials. A salt-and-water solution is obviously different from a sugar-and-water solution, especially to anyone who has made a substitution error when making lemonade. Second, solutions can be made from the same materials, but the ratio of solute (the solid) to solvent (the liquid) can differ. This ratio is called concentration. Solutions with a high ratio of solute to solvent are concentrated solutions. Solutions with a low ratio of solute to solvent are dilute solutions.
Consider a salt-and-water solution. A spoonful of table salt (sodium chloride) dissolves in a glass of water, making a dilute, clear, colorless solution. A second spoonful and then a third will dissolve in the water, making the solution more concentrated with each additional spoonful of salt. However, an interesting thing happens when the fourth spoonful of salt is added: it sits on the bottom of the glass and does not dissolve. All solutions eventually reach a point where no more solute can dissolve in the solvent. When this happens, the solution has reached its maximum concentration and is said to be saturated. The amount of solid material needed to saturate a given volume of water varies greatly, depending on the solute used. For instance, only a gram (g) or two of sodium bicarbonate (baking soda) saturates 50 milliliters (mL) of water, but more than 50 g of citric acid saturates the same volume of water.

Separating solutions into their component parts can usually be accomplished by evaporation. In evaporation, the solvent vaporizes (turns into a gas) and is carried off by the surrounding air. The solute is left behind. In most cases, the solid material comes out of solution as distinctive crystals. Each kind of solid material has its own natural form, dictated by the way the material’s particles align with one another. Salt forms cubic crystals; calcium acetate forms long, needlelike crystals; and Epsom salts form six-sided polygons.

When a solid material dissolves and seems to disappear in a liquid, it undergoes a physical change. The size of the particles or the way the particles relate to one another may change, but it is still the same material.

**Chemical Reactions**

When two solutions are mixed, another kind of change could take place—a chemical change. When this happens, the result is a chemical reaction. The starting substances (reactants) change into new substances (products). New materials form as a result of chemical reactions, and it is not possible to retrieve the original materials without another chemical reaction.

Consider this example of a chemical reaction: you have excess hydrochloric acid, giving you a pain in the stomach. You make a solution using an antacid tablet containing baking soda (sodium bicarbonate) and drink it. In your stomach, the two materials mix and react. The acid and baking soda are used up, and new products form: sodium chloride (table salt), water, and carbon dioxide. Voilà! No more stomachache. The carbon dioxide is released with a belch, the salt is dispatched by the bloodstream, and a little extra water is gained.
**Engineering Design**

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

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

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

**Defining the problem** involves an understanding of criteria and constraints. In the first investigation in the module, the constraints are on the tools available to separate the materials in a mixture of several solid materials in water. The criteria is that each material needs to be separated from the water. In Investigation 4, students are challenged to apply their knowledge of solution chemistry to design a process (only the design process) to make ocean water suitable for drinking. In this case, the constraints are the processes that can be applied and the criteria is to have drinkable water.

**Developing possible solutions** involves comparing alternative solutions to see which solution best meets the criteria and constraints of the problem. Groups work collaboratively on several designs to separate a mixture into its components and later to turn salt water into drinkable water.

**Improving the design** involves testing the prototype using fair tests, trying to control all variables, and changing only one variable at a time. Students need to know that “failure” is not only OK, but expected in engineering design. Having something fail drives you to improve
the system and make progress. Collaboration is an important aspect of engineering design; learning from the successes and failures of other design groups can be very productive. Students can engage in engineering practices without fully engaging in the iterative process of design.

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

### CONCEPTUAL FRAMEWORK

**Engineering Design: Energy**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Concept A** | Defining and delimiting engineering problems.  
- 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. |
| **Concept B** | Developing possible solutions.  
- Research before designing, testing possible solutions, communicating with peers about possible solutions are all important parts of the design process. Tests are designed to identify inadequacies which will suggest design elements to improve. |
| **Concept C** | Optimizing the design solution.  
- Different solutions need to be tested in order to determine which of them best achieves the most satisfactory solution to the problem, given the criteria and the constraints. |
Matter Content Sequence

This table shows the five FOSS modules and courses that address the matter content sequence, grades K–8. Running through the sequence are the two progressions—matter has structure, and matter interacts. The supporting elements in each module (somewhat abbreviated) are listed. The elements for the Mixtures and Solutions Module are expanded to show how they fit into the sequence.

<table>
<thead>
<tr>
<th>Module or course</th>
<th>Matter has structure</th>
<th>Matter interacts</th>
</tr>
</thead>
</table>
| **Chemical Interactions**<br>(middle school) | • Matter is made of atoms.  
• Substances are defined by chemical formulas.  
• Elements are defined by unique atoms.  
• The properties of matter are determined by the kinds and behaviors of its atoms.  
• Atomic theory explains the conservation of matter. | • During chemical reactions, particles in reactants rearrange to form new products.  
• Energy transfer to/from the particles in a substance can result in phase change.  
• During dissolving, one substance is reduced to particles (solute), which are distributed uniformly throughout the particles of the other substance (solvent). |
| **Mixtures and Solutions**<br>(grade 5) | | |
| **Motion and Matter**<br>(grade 3) | • Measurement can be used to confirm that the whole is equal to its parts. | • A mixture is two or more intermingled substances.  
• Mass is conserved when objects or materials are mixed. |
| **Solids and Liquids**<br>(grade 2) | • Common matter is solid, liquid, and gas.  
• Solid matter has definite shape.  
• Liquid matter has definite volume.  
• Gas matter has neither definite shape nor volume and expands to fill containers.  
• Intrinsic properties of matter can be used to organize objects (e.g., color, shape). | • Solids interact with water in various ways: float, sink, dissolve, swell, change.  
• Liquids interact with water in various ways: layer, mix, change color.  
• Substances change state (e.g., melt or freeze) when heated or cooled. |
| **Materials and Motion**<br>(grade k) | • Wood, paper, rock, and fabric are examples of solid materials.  
• Solid objects are made of solid materials.  
• Solid objects have properties.  
• The whole (object) can be broken into smaller pieces. | • Wood, paper, and fabric can be changed by sanding, coloring, tearing, etc.  
• Common materials can be changed into new materials (paper making, weaving, etc.). |
**NOTE**

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

The NGSS Performance Expectations addressed in this module include:

**Physical Sciences**
- 5-PS1-1
- 5-PS1-2
- 5-PS1-3
- 5-PS1-4

**Engineering, Technology, and Applications of Science**
- 3–5 ETS1-1
- 3–5 ETS1-2
- 3–5 ETS1-3

See pages 32–35 in this chapter for more details on the Grade 5 NGSS Performance Expectations.
CONNECTIONS TO NGSS BY INVESTIGATION

**Science and Engineering Practices**

**Inv. 1: Separating Mixtures**
- Defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

**Inv. 2: Developing Models**
- Defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

**Connections to Common Core State Standards—ELA**

**RF 4:** Read with sufficient accuracy and fluency to support comprehension.

**RI 1:** Quote accurately from a text when explaining what the text says explicitly and when drawing inferences.

**RI 2:** Determine main ideas of a text and explain how they are supported by key details; summarize the text.

**RI 4:** Determine the meaning of general academic and domain-specific words and phrases in a text.

**RI 7:** Draw on information from multiple print or digital sources to locate an answer to a question quickly.

**RI 8:** Explain how an author uses reasons and evidence to support particular points in a text.

**RI 9:** Integrate information from several texts on the same topic in order to write or speak about the subject.

**W 4:** Produce clear and coherent writing.

**W 5:** Develop and strengthen writing.

**W 8:** Recall relevant information from experiences or gather relevant information; take notes.

**W 9:** Draw evidence from informational texts.

**SL 2:** Summarize a written text read aloud or information presented in diverse media.

**SL 4:** Report on a topic, sequencing ideas logically.

**SL 6:** Adapt speech to a variety of contexts and tasks.

**L 3:** Use knowledge of language and its conventions when writing, speaking, reading, or listening.

**L 4:** Determine or clarify the meaning of words.

**L 5:** Demonstrate understanding of word relationships.

**L 6:** Acquire and use academic and domain-specific words.
### Disciplinary Core Ideas

**PS1.A: Structure and properties of matter**
- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)

**ETS1.A: Defining and delimiting engineering problems**
- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed 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. (3–5-ETS1-1)

**ETS1.B: Developing possible solutions**
- 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. (3–5-ETS1-2)

**ETS1.C: Optimizing the design solution**
- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3–5-ETS1-3)

### Crosscutting Concepts

- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
MIXTURES AND SOLUTIONS

Science and Engineering Practices

- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Connections to Common Core State Standards—ELA

- RF 4: Read with sufficient accuracy and fluency to support comprehension.
- RI 1: Quote accurately from a text when explaining what the text says explicitly and when drawing inferences.
- RI 2: Determine main ideas of a text and explain how they are supported by key details; summarize the text.
- RI 3: Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a scientific text based on specific information in the text.
- RI 4: Integrate relevant information from several texts on the same topic in order to write or speak about the subject.
- RI 5: Compare and contrast the overall structure of events, ideas, concepts, or information in two or more texts.
- RI 6: Analyze multiple accounts of the same event or topic, noting important similarities and differences.
- RI 7: Draw on information from multiple print or digital sources to locate an answer to a question quickly.
- RI 8: Explain how an author uses reasons and evidence to support particular points in a text.
- W 5: Develop and strengthen writing.
- W 7: Conduct short research projects.
- W 8: Recall relevant information from experiences or gather relevant information; take notes.
- SL 1: Engage in collaborative discussions.
- SL 2: Summarize a written text read aloud or information presented in diverse media.
- SL 4: Include multimedia components and visual displays in presentations.
- L 4: Determine or clarify the meaning of words.
- L 5: Demonstrate understanding of word relationships.
## Disciplinary Core Ideas

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- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)
- Measurements of a variety of properties can be used to identify materials. (5-PS1-3)

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## Crosscutting Concepts

- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter

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### Crosscutting Concepts

- **Cause and effect**
- **Scale, proportion, and quantity**
- **Systems and system models**
- **Energy and matter**
**Science and Engineering Practices**

- Asking questions
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations
- Obtaining, evaluating, and communicating information

**Connections to Common Core State Standards—ELA**

- **RF 4:** Read with sufficient accuracy and fluency to support comprehension.
- **RI 1:** Quote accurately from a text when explaining what the text says explicitly and when drawing inferences.
- **RI 2:** Determine main ideas of a text and explain how they are supported by key details; summarize the text.
- **W 8:** Recall relevant information from experiences or gather relevant information; take notes and categorize information.
- **SL 1:** Engage in collaborative discussions.
- **SL 4:** Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes.
- **L 5:** Demonstrate understanding of word relationships.

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**PS1.A: Structure and properties of matter**

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**(5-PS1-2)**

- Measurements of a variety of properties can be used to identify materials.

**(5-PS1-3)**

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**PS1.B: Chemical reactions**

- When two or more different substances are mixed, a new substance with different properties may be formed.

**(5-PS1-4)**

- No matter what reaction or change in properties occurs, the total weight of the substances does not change.

**(5-PS1-5)**

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**Cause and effect**

**Scale, proportion, and quantity**

**Systems and system models**

**Energy and matter**
## Disciplinary Core Ideas

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## Crosscutting Concepts

- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
## RECOMMENDED FOSS NEXT GENERATION K–8
### SCOPE AND SEQUENCE

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*Half-length courses

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