



Smithsonian

STC

SCIENCE AND TECHNOLOGY CONCEPTS™

MIDDLE SCHOOL

Matter and Its Interactions

Unit Sampler

Teacher Edition

CAROLINA
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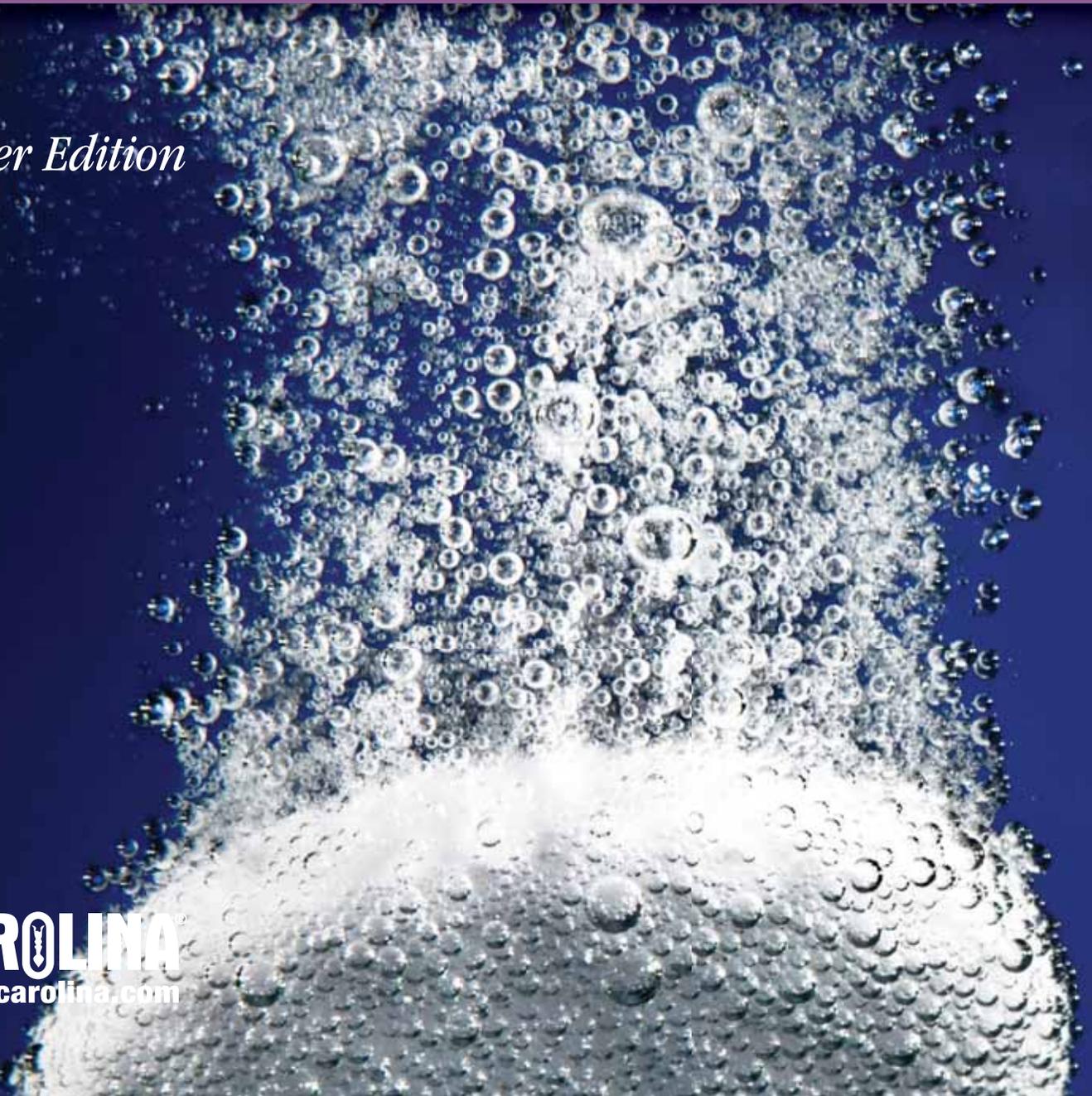


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Matter and Its Interactions Three-Dimensional Instruction Sampler

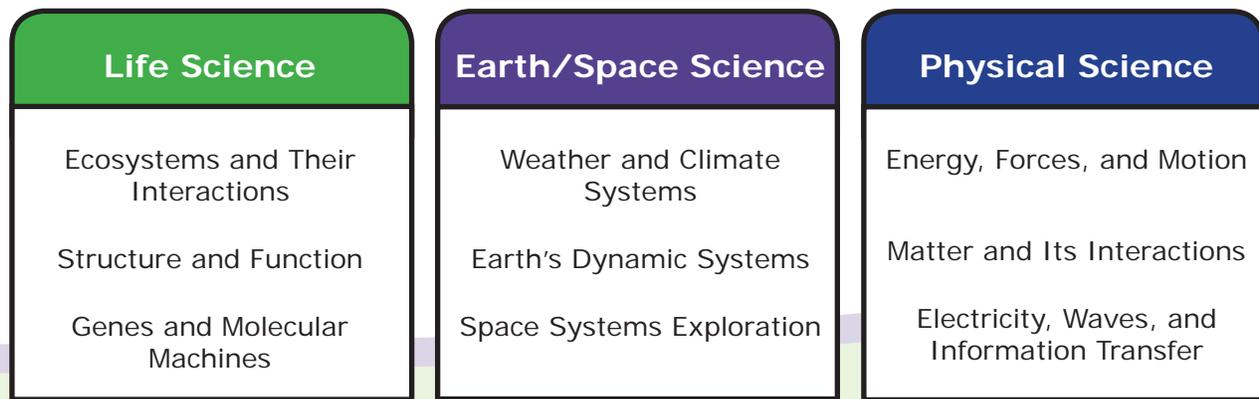
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9 All-New Units for Middle School from the Smithsonian!

Smithsonian’s STCMS Is Built to Meet the Next Generation Science Standards and Incorporate the 5 Innovations:

- **Three-dimensional learning** construction—every lesson, every unit
- Lessons that apply **science concepts** to NGSS* **engineering design**
- Hands-on investigations in which students build explanations for real-world **phenomena and design solutions—every day**
- **Coherent learning progression** that develops lesson by lesson, unit by unit—no “random acts of science”
- **Literacy and mathematics connections** that bridge science content and lead to deep understanding

STCMS Learning Framework



Hands Down, Research Tells Us that Inquiry-Based Instruction Is Best for Your Students

Choose instruction that has been proven to improve student performance and test scores not only in science, but also in reading and math. ♦

What students say about STC:

“In science you do hands-on activities instead of just writing and doing notes, and you get to work with people. For visual people in science that’s a lot better because you get to see the experience and experiment.”

What administrators say about STC:

“We saw instant results in our test scores—a double-digit increase in our end-of-grade state performance...”

♦ *Visit www.carolina.com/stc to download the LASER i3 Study Results*

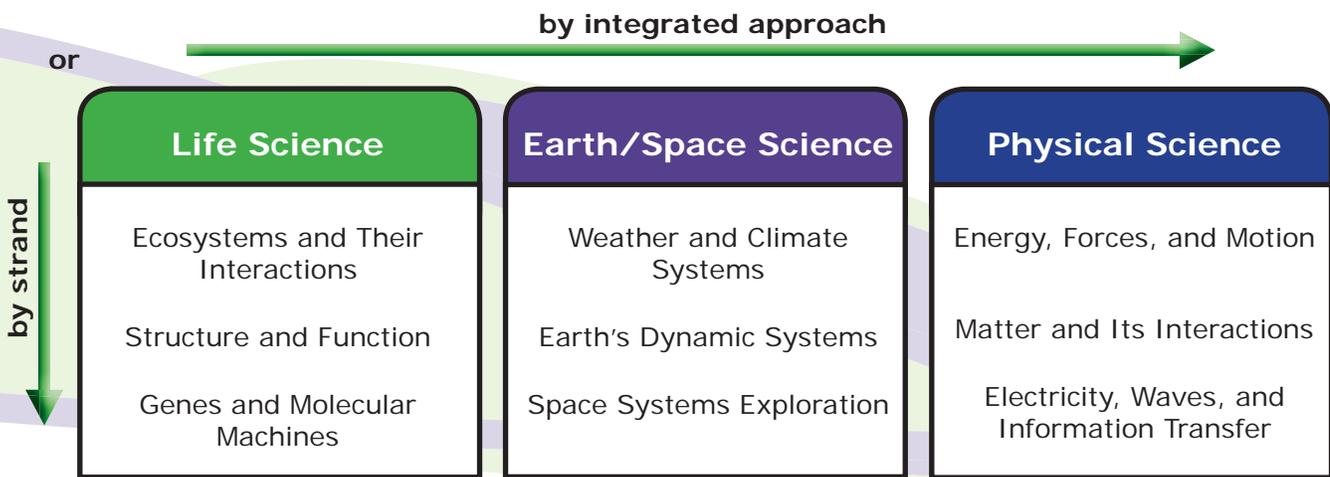
* Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

Coherent Learning Progressions—Lesson by Lesson, Unit by Unit

The NGSS provide students with continued opportunities to engage in and develop a deeper understanding of the three dimensions of science. The STCMS program follows this coherent learning progression, lesson by lesson, unit by unit.

The STCMS Learning Framework—Conceptual Progression by Unit

Three units in each strand of Physical, Life, and Earth/Space Science allows you to build your middle school program



An example of how concepts can grow across a strand within STCMS

Physical Science Concepts

Energy, Forces, and Motion develops the energy background on how visible objects move and collide resulting in energy transfer and ending with how energy can be transformed.



Matter and Its Interactions builds understanding of the relationship between energy and matter and transfer and transformation at the molecular level.



Electricity, Waves, and Information Transfer studies and builds an understanding of the transfer and transformation of energy, how specific energies are transmitted by waves, and the technology contributions to society that have resulted from this understanding.

Three-Dimensional Learning—The Signature Innovation of the Next Generation Science Standards

STCMS provides teacher support in weaving together Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts to address Performance Expectations over time.



Density Makes a Difference

STCMS meets the 5 Innovations of NGSS, deepening understanding of Performance Expectations

Alignment to Next Generation Science Standards

- MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Lesson 3 aligns in part to NGSS **performance expectation MS-PS1-2** by providing students with practice in defining a physical property—density, which is specific to all pure substances and can be used to identify them. Students perform investigations that provide evidence that clarifies this concept. In Investigation 3.1, students determine that the density is the same for different sample sizes of the same substance, water. In Investigations 3.2 and 3.3, students determine the densities of different materials and associate the property as a defining characteristic of each of those materials. In Investigations 3.4 and 3.5, students combine substances and observe their interactions, noting that the property of density remains unchanged and accounts for the behavior of the substances.

This lesson incorporates the **science and engineering practice of analyzing and interpreting**

data. Throughout Investigations 3.1, 3.2, and 3.3, students measure mass and volume and calculate density. They **interpret and analyze that data**, using it to make predictions, in Investigations 3.4 and 3.5. The density column and density bottles students build in Investigations 3.4 and 3.5 also engage students in the **engineering practice of developing and using models.**

Lesson 3 addresses the **crosscutting concept** that macroscopic **patterns** are related to the nature of microscopic and atomic-level structure. Students learn that density is related to mass and arrangement of the particles that make up substances and that these characteristics are consistent from sample to sample for a given substance. Lesson 3 also addresses the **crosscutting concept of cause and effect** as students look for causal reasons that explain the behavior of materials when combined. Finally, this lesson also addresses the **crosscutting concept of scale proportion and quantity** as students use models to observe phenomena and study systems that are too small to observe and study otherwise.

Complete Three-Dimensional Learning Support

Three-Dimensional Learning in *Matter and Its Interactions* Is Lessons that:

- Ignite learning through phenomena
- Explore phenomena through experiential learning
- Use models to represent systems, develop questions and explanations, generate data, and communicate ideas
- Integrate literacy and math
- Convert learning experiences into understanding of phenomena

Alignment to the Next Generation Science Standards

Alignment to Next Generation Science Standards

Alignment of *Matter and Its Interactions* to Next Generation Science Standards

PERFORMANCE EXPECTATIONS

- MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
- MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
- MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.
- MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.
- MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

SCIENCE AND ENGINEERING PRACTICES

- Asking questions and 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
- Connections to Nature of Science: Scientific knowledge is based on empirical evidence
- Connections to Nature of Science: Science models laws, mechanisms, and theories to explain natural phenomena

CROSSCUTTING CONCEPTS

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change
- Connections to engineering, technology, and applications of science: interdependence of science, engineering, and technology
- Connections to engineering, technology, and applications of science: influence of science, engineering, and technology on society and the natural world

DISCIPLINARY CORE IDEAS

- PS1.A: Structure and properties of matter
- PS1.B: Chemical reactions
- PS3.A: Definitions of energy
- ETS1.A: Defining and delimiting engineering problems
- ETS1.B: Developing possible solutions
- ETS1.C: Optimizing the design solution

A Coherent Learning Progression within Each Unit

STCMS Program units develop logically and systematically to build a deep understanding of content and science and engineering practices.

From pre-assessment to summative performance assessment, students have multiple opportunities to build understanding by engaging in investigations. Within *Matter and Its Interactions*, students build understanding of matter and how its interactions affect everyday life.

This sampler highlights a specific group of investigations from three lessons that directly support performance expectation:

MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Three-dimensional understanding of this performance expectation builds throughout the unit. This sampler focuses on three specific opportunities: the Pre-Assessment, further investigation in Lesson 3, and the Performance Assessment in Lesson 11.

In the **Pre-Assessment**, students visit eight investigation stations to assess what they already know about matter. Investigation 1.6: Beads in a Bottle, is an introduction to Lesson 3: Density Makes a Difference. Students are asked to make a claim about the substances they think make up the contents of the bottle and state the evidence they have to support this claim.



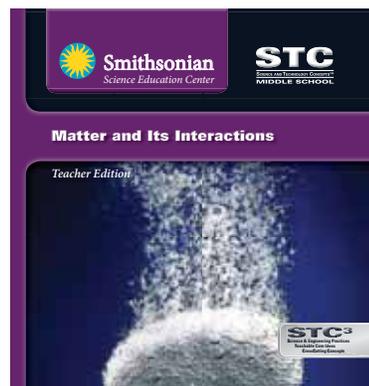
Figure 1.3
Sample illustration of beads before shaking



In **Lesson 3: Density Makes a Difference**, students relate the density of a substance or object to the organization of its particles, and by doing so gain understanding that density is a characteristic property that can be used to identify substances. Investigation 3.5: Building a Density Bottle challenges students to use their understanding of substances and their densities to recreate the bottle from Pre-Assessment Investigation 1.6. Then, students apply their knowledge about matter and how it interacts to create a new cold pack design for a manufacturing company in the **Lesson 11 Performance Assessment**.

In STCMS:

- Units average 11 lessons
- Lessons average 5–6 investigations
- Investigations are based on 45- to 50-minute sessions
- Unit completion averages 12 weeks



Details on what is included in a unit can be found on the back cover of this sampler.

Coherent Learning Progression—Lesson by Lesson

A
 systematic
 approach builds deep
 three-dimensional
 understanding

Concept Storyline

Matter and Its Interactions Concept Storyline

● Unit Driving Question: How does matter and its interactions affect everyday life?

Lesson 1: Pre-Assessment: Matter and Its Interactions

Focus Question: What do you know about matter?

Students perform short, simple investigations that evaluate their existing knowledge of one or more concepts related to matter and its interactions. Students make observations of pure substances and mixtures and determine if new substances are formed. Students also evaluate predictions, use evidence to support claims, and infer cause-and-effect relationships.

Lesson 2: The Nature of Matter

Focus Question: What can properties of matter help you determine?

Students observe and describe samples of matter based on their physical and chemical properties (including solubility, and reactivity). Students also identify mystery samples on the basis of their physical and chemical properties.

Lesson 3: Density Makes a Difference

Focus Question: How can density be used to identify a substance and predict how it will behave under different conditions?

Students compare the densities of different substances, including liquids and irregularly shaped objects. Students also make and test predictions about the floating of solids in liquids and use their findings to re-create the density bottle they explored in the Pre-Assessment.

Lesson 4: Just a Phase

Focus Question: How is energy related to physical changes in matter?

Students record the temperature of water as it melts, warms, and boils and then make connections with molecular-level observations in a computer simulation of the same experiment. Students also apply their understanding of the law of conservation of mass to plan and carry out investigations of the mass of water as it melts or freezes in a sealed container.

Lesson 5: Building Blocks of Matter

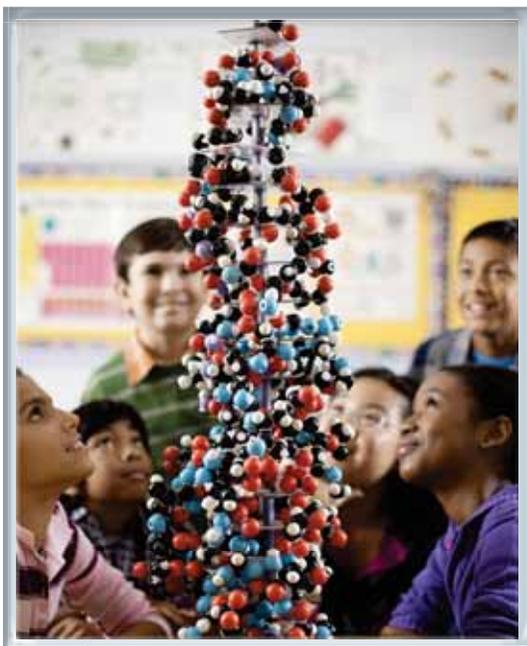
Focus Question: How can you use a model to describe the composition of matter?

Students rotate through stations to collect information about 16 different element samples. Next, students combine elements and create models of simple molecules using plastic atoms and computer simulations.

Lesson 6: Pure Substances and Mixtures

Focus Question: How can mixtures be separated?

Students observe and describe samples of pure substances and mixtures. Students use chromatography to separate inks, and distill flavoring from a carbonated beverage. Students apply engineering skills to design a method for removing impurities from rock salt.



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• **Lesson 7: Reacting Chemically**

Focus Question: How can the properties of matter be used to determine if a chemical reaction has occurred?

Students analyze and interpret data on the properties of substances before and after different chemical reactions. Students also use their data to support the claim that a new substance has been formed. Chemical reactions include: the electrolysis of water; formation of precipitates; and combination of sodium bicarbonate, calcium chloride, and phenol red.

Lesson 8: Releasing Energy

Focus Question: What is the relationship between changes in substances and changes in thermal energy?

Students investigate a physical change that releases energy (dissolving calcium chloride in water). Next, students use data from their investigation to design a device that provides heat on demand: an instant hot pack.

Lesson 9: Conservation of Matter

Focus Question: What happens to matter in a chemical reaction?

Students will apply their understanding of the law of conservation of matter to create models that explain situations in which matter seems to appear or disappear. Chemical reactions include dissolving an effervescent tablet in water and burning steel wool.

Lesson 10: Compounds from Natural Resources

Focus Question: How are synthetic compounds made and used?

Students read about and investigate natural resources that undergo chemical reactions to produce synthetic materials. Students plan and conduct an investigation to determine which solutions can be combined with sodium alginate to form a gelatinous product.

Lesson 11: Assessment: Matter and Its Interactions

Focus Question: How can we use our knowledge of matter and its interactions to solve problems?

The unit concludes with a two-part assessment. The first part is a Performance Assessment, in which students demonstrate their content knowledge and science and engineering skills to design a cold pack using one of five chemical compounds. Students must set up their own experiments and justify their selection based on safety for humans, safety for the environment, and cost of material per gram. In the second part, students complete a Written Assessment covering the performance expectations, disciplinary core ideas, crosscutting concepts, and science and engineering practices covered in this unit.

More resources for teachers and students found at:
www.carolinascienceonline.com
www.ssec.si.edu/STCMS



NASA/Dana Berry

Non-Fiction Literacy Connected to Science Phenomena

Non-fiction literacy selections introduce students to phenomena and support their experiential learning, deepening their understanding.

Introduce Science Phenomena through Non-Fiction Literacy



HAVE YOU EVER WONDERED?

Read
Selection

What Is Matter?

All the substances that make up everything in the universe are forms of matter. Each pure substance has characteristic properties—both physical and chemical. All matter has mass. We can find out how much matter an object contains by measuring its mass. Mass is measured in grams (g) or kilograms (kg).

All living things are made up of matter. Matter in living things has the same properties as matter in nonliving things.

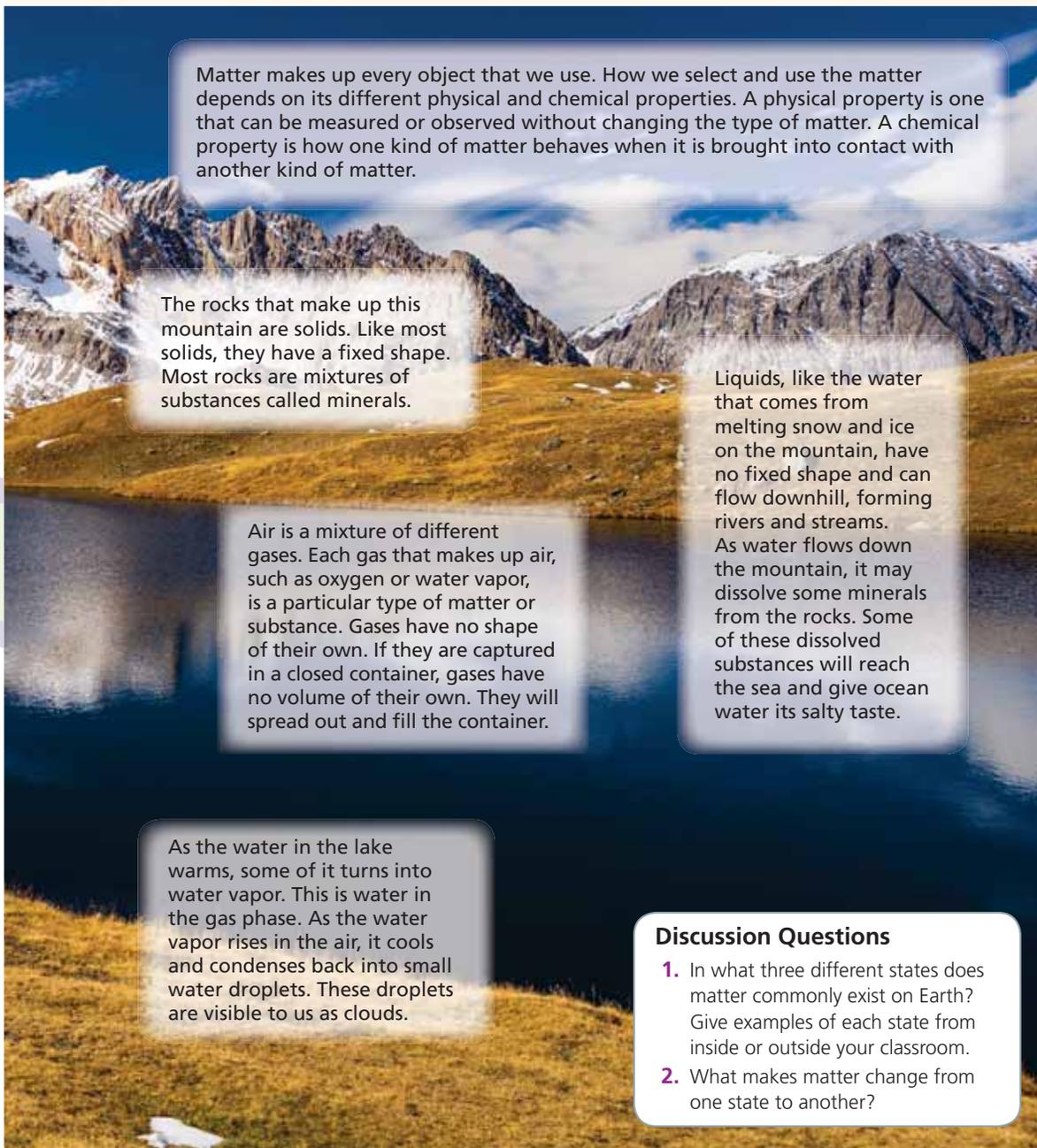
Liquid matter, like the water in this lake, can flow from one place to another and will settle to the bottom of a container.

Matter also takes up space. The volume of matter is measured in milliliters (mL) and liters (L). Volume may also be measured in cubic centimeters (cm³) and cubic meters (m³). Therefore, two properties of matter are that it has mass and volume.

On Earth, matter commonly exists in one of three phases, or states: solid, liquid, and gas. Changes in state occur with variations in temperature. The snow on this mountain is water in the solid state. As the snow absorbs heat from the Sun, it will start to melt into its liquid form, water. If the water evaporates, it will become water vapor, a gas. Water is special because it exists in nature in three different phases. Can you think of any other substance that is found in nature in all three of these phases?

Our bodies are made up of matter. For example, water is the most common substance in our bodies. Water plays an important part in almost every body process. The physical and chemical properties of matter enable our bodies to work. For example, we use the chemical properties of food matter to obtain the energy we need to live.

**ELA
Connection
RI.6.1**



Matter makes up every object that we use. How we select and use the matter depends on its different physical and chemical properties. A physical property is one that can be measured or observed without changing the type of matter. A chemical property is how one kind of matter behaves when it is brought into contact with another kind of matter.

The rocks that make up this mountain are solids. Like most solids, they have a fixed shape. Most rocks are mixtures of substances called minerals.

Liquids, like the water that comes from melting snow and ice on the mountain, have no fixed shape and can flow downhill, forming rivers and streams. As water flows down the mountain, it may dissolve some minerals from the rocks. Some of these dissolved substances will reach the sea and give ocean water its salty taste.

Air is a mixture of different gases. Each gas that makes up air, such as oxygen or water vapor, is a particular type of matter or substance. Gases have no shape of their own. If they are captured in a closed container, gases have no volume of their own. They will spread out and fill the container.

As the water in the lake warms, some of it turns into water vapor. This is water in the gas phase. As the water vapor rises in the air, it cools and condenses back into small water droplets. These droplets are visible to us as clouds.

Discussion Questions

1. In what three different states does matter commonly exist on Earth? Give examples of each state from inside or outside your classroom.
2. What makes matter change from one state to another?

PHOTO: Fabio Lamanna/Shutterstock.com

What Do They Already Know?

Pre-assessment investigations help teachers gain insight into students' prior knowledge and misconceptions. Pre-assessments introduce students to science phenomena they will investigate throughout the unit, beginning the construction of deep understanding and the ability to explain phenomena.

Investigation 1.6: *Beads in a Bottle* asks students to make a claim about the substances they think make up the contents of the bottle and what evidence they have to support this claim.



Investigation 1.6: Beads in a Bottle

Procedure

1. Instruct groups to move to their assigned stations. Remind them to review the instructions provided in their Student Guide and to use their science notebooks for recording their observations.
2. Students' illustrations should look similar to TE Figure 1.3. Students may describe beads floating in the

center of the bottle. Students should observe and describe the obvious physical properties of the beads and the liquid. Students may state that the bottle contains two different solids and a colorless liquid. (The bottle actually contains two colorless liquids, but this may not be obvious to students.)



Figure 1.3
Sample illustration of beads before shaking

Note: Students will use their understanding of density to recreate the bottle used in this investigation later in the unit (during Lesson 3). Do not reveal the identity of the two liquids to students during Lesson 1.

3. Students should state that there are multiple distinct substances in the bottle: liquid and two types of beads. Look for students who understand that there may be two different colorless liquids in the bottle, recognizing that the different densities of the liquids cause them to separate into layers.

4. When the bottle is shaken, it forms a colorless emulsion (mixture of immiscible liquids). Students should observe that the green beads sink to the bottom and the UV beads rise to the top. After a few seconds, the two liquids will separate. Both types of beads will return to the interface between the layers.

continued

Investigation 1.6

Beads in a Bottle

Materials

For you

- Science notebook
- Safety goggles

For your group

- 1 Bottle containing beads

Procedure

1. At this station, you and your group will determine if mixing results in the formation of a new substance.
2. Look at the contents of the bottle. Sketch a picture of the bottle in your science notebook. Together with your group, discuss what you know about the substances in the bottle. Record your responses in your science notebook.
3. How many different substances do you think are in the bottle? What evidence do you have to support this claim? Discuss these questions with your group and record your responses in your science notebook.
4. Shake the bottle two times and observe it for one minute. Record your observations in your science notebook.
5. Once again, shake the bottle two times and observe it. Sketch pictures in your science notebook to document how the bottle changes after shaking.
6. Using your observations, what additional things do you know about the substances in the bottle now that you have shaken it?
7. Do you think the number of substances in the bottle is different after you shook it? What evidence do you have to support this claim?
8. Restore the station to its original condition for the next group.

Figure 1.7
How many different substances do you think are in the bottle?
PHOTO: © Carolina Biological Supply Company





Pre-Assessment: Matter and Its Interactions

Use pre-assessments to introduce phenomena and identify misconceptions early on

Investigation 1.6: Beads in a Bottle *continued*

5. Students' illustrations should look similar to TE Figures 1.4, 1.5, and 1.6.
6. If they have not done so previously, students are likely to state that there are two distinct liquids in the bottle. Focus on student observations that describe how, although the liquids are colorless, they have densities that cause them to separate in the bottle. The beads also have different densities, causing them to form two distinct groups. Students may not use the word density but they might describe one liquid or solid as being heavier or lighter than another.
7. Students should indicate that the bottle contains the same number of substances before and after shaking. Eventually, the emulsion will again separate into two liquids and the beads will return to their original position. Look for students who incorrectly state that a new substance is formed. These students may not understand what substances are (scientifically) or may believe that mixing always results in the formation of a new substance.
8. Students should restore the station to its original condition for the next group.



Figure 1.4
Sample illustration showing bottle with UV beads at top and green beads at bottom

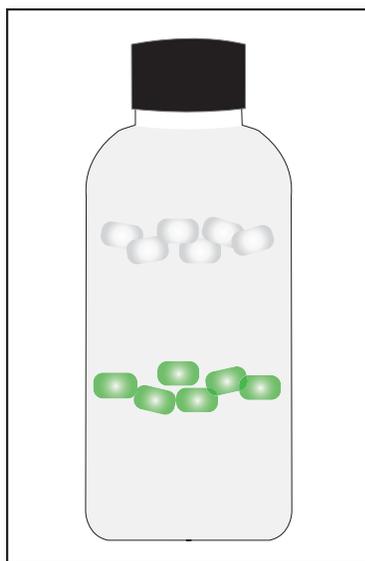


Figure 1.5
Sample illustration showing UV beads lower and green beads higher

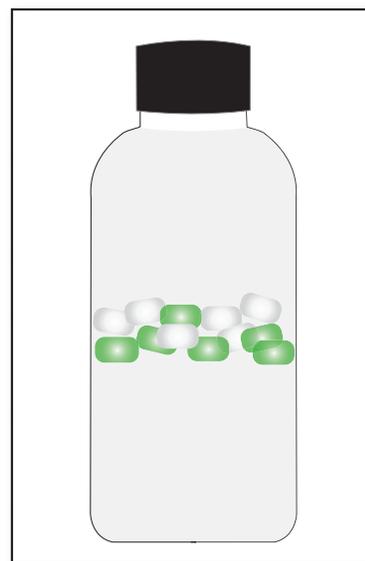


Figure 1.6
Sample illustration showing beads returning to their original position in the bottle

NGSS, English Language Arts, and Math Standards

Lesson at a Glance provides an overview of each lesson, including lesson-specific correlations to the NGSS and connections to English Language Arts and Math Standards.



Density Makes a Difference

	GETTING STARTED	INVESTIGATION 3.1: Measuring the Mass, Volume, and Density of Liquids	INVESTIGATION 3.2: Comparing the Densities of Different Substances	INVESTIGATION 3.3: Measuring the Densities of Irregular Objects	
Overview	<ul style="list-style-type: none"> Students read Building Your Knowledge: <i>Density as a Physical Property</i> and then model the organization of molecules in two objects of different densities. Students describe how density can be used to identify substances. 	<ul style="list-style-type: none"> Students read Building Your Knowledge: <i>Calculating Density</i> and then plan and carry out an investigation to determine if different volumes of water will have the same density. Students also plan and carry out an investigation to determine if different liquids have the same density. 	<ul style="list-style-type: none"> Students predict the relative densities of four blocks of different materials, draw models to describe the particles they contain, and then plan and carry out an investigation to evaluate their predictions. Students revise the models they created to reflect evidence gathered during their investigation. 	<ul style="list-style-type: none"> Students plan and carry out an investigation determining the densities of irregularly shaped objects. Students read Building Your Knowledge: <i>Why Bother with Density?</i> 	
Objectives	<ul style="list-style-type: none"> Relate the density of a substance or object to the organization of its particles. Understand that density is a characteristic property that can be used to identify substances. 	<ul style="list-style-type: none"> Understand the relationship between mass, volume, and density. Use mass and volume to calculate density. 	<ul style="list-style-type: none"> Calculate and compare the densities of various regular solids. 	<ul style="list-style-type: none"> Devise a method for determining the densities of irregular objects. Measure the densities of irregular objects. 	
Concepts	<ul style="list-style-type: none"> Density is a physical property that can be used to distinguish substances. 	<ul style="list-style-type: none"> Graduated cylinders and electronic balances are tools used to measure the volume and mass of liquids. 	<ul style="list-style-type: none"> Different substances possess different densities. 	<ul style="list-style-type: none"> The volume of an irregular object can be determined indirectly. 	
Assessment	Formative	Formative	Formative	Formative	
Key Terms	Density Mass Model Physical property Volume	Characteristic property Density Mass Modification Predict Volume	Diagram Model Modification Particle Predict	Contraction Density Expansion	
Time	1 period	2 periods	1 period	1 period	
Standards	ALIGNMENT TO NEXT GENERATION SCIENCE STANDARDS Performance Expectations <ul style="list-style-type: none"> MS-PS1-2 Science and Engineering Practices <ul style="list-style-type: none"> Developing and using models Analyzing and interpreting data Crosscutting Concepts <ul style="list-style-type: none"> Patterns Cause and effect Scale, proportion, and quantity Disciplinary Core Ideas <ul style="list-style-type: none"> PS1.A: Structure and properties of matter 				



LESSON AT A GLANCE

	INVESTIGATION 3.4: Building a Density Column	INVESTIGATION 3.5: Building a Density Bottle	REFLECTING ON WHAT YOU'VE DONE	EXTENDING YOUR KNOWLEDGE READING SELECTIONS
	<ul style="list-style-type: none"> Students analyze and interpret the experimentally determined densities of solids and liquids to predict the behavior of materials when they are combined in a plastic cylinder. Students analyze and interpret data on new substances and make inferences about their density. 	<ul style="list-style-type: none"> Students will apply what they have learned to design a density bottle similar to the one they investigated in the pre-assessment lesson. Students analyze and interpret data comparing their density bottle with data collected in the pre-assessment to evaluate whether or not the bottles contain the same substances. 	<ul style="list-style-type: none"> Students use their understanding of density to explain real-life phenomena. Students develop models to explain and predict real-life phenomena. Students read Extending Your Knowledge: <i>Archimedes's Crowning Moment</i>. 	<ul style="list-style-type: none"> <i>Archimedes's Crowning Moment</i> describes Archimedes's discovery of the relationships among density, volume, and the displacement of water. <i>Panning for Gold</i> describes the process by which some prospectors separated bits of gold from debris in streams, a process that depends on density differentials. <i>Panda Poop</i> explains how scientists at The Smithsonian National Zoological Park use density to help animal caretakers know when pandas are fertile.
	<ul style="list-style-type: none"> Use density to predict whether objects will float or sink in liquids. Make observations to confirm or refute predictions. 	<ul style="list-style-type: none"> Infer the relative density of a liquid from the behavior of solids of known densities. 	<ul style="list-style-type: none"> Explain how density affects the behavior of objects in the real world. 	<ul style="list-style-type: none"> <i>Archimedes's Crowning Moment</i> Appreciate how a serendipitous observation by a prepared mind can lead to a scientific discovery. <i>Panning for Gold</i> Compare and contrast the densities of various substances to separate them from a mixture. <i>Panda Poop</i> Read about how centrifuging is used by scientists to measure hormone levels in pandas.
	<ul style="list-style-type: none"> Floating and sinking are observable evidence of the relative densities of different materials. 	<ul style="list-style-type: none"> The approximate density of a liquid can be determined by observing the behavior of objects of known densities in the liquid. 	<ul style="list-style-type: none"> Observations of common events can be explained by applying the principles of density. 	<ul style="list-style-type: none"> An object immersed in water will displace a volume of water equal to the volume of the object. Solid materials of different densities can be separated in a fluid because the denser material will tend to accumulate beneath the less dense material. Compounds with different densities can be separated using a centrifuge.
	Formative	Formative	Formative	
	Density Diagram Predict	Density Diagram Model Predict	Density Diagram Model Particles	Atom Density Mass Molecule Physical property Volume
	1 period	1 period	1 period	



CONNECTIONS

English Language Arts

- RST.6-8.3 Key ideas and details
- RST.6-8.10 Range of reading and level of text complexity
- SL.6.1 Comprehension and collaboration
- WHST.6-8.2 Text types and purposes

Mathematics

- MP5 Use mathematical tools appropriately.
- 6.EE.A.2.C Apply and extend previous understandings of arithmetic to algebraic expressions.

Support for Teachers During the Transition to NGSS

Lesson-specific alignment to NGSS makes it clear how each part of the standards is tackled, ensuring true three-dimensional learning.



Density Makes a Difference

Lesson-specific correlations tell you the what and how of NGSS—in every lesson

Alignment to Next Generation Science Standards

- MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Lesson 3 aligns in part to NGSS **performance expectation MS-PS1-2** by providing students with practice in defining a physical property—density, which is specific to all pure substances and can be used to identify them. Students perform investigations that provide evidence that clarifies this concept. In Investigation 3.1, students determine that the density is the same for different sample sizes of the same substance, water. In Investigations 3.2 and 3.3, students determine the densities of different materials and associate the property as a defining characteristic of each of those materials. In Investigations 3.4 and 3.5, students combine substances and observe their interactions, noting that the property of density remains unchanged and accounts for the behavior of the substances.

This lesson incorporates the **science and engineering practice of analyzing and interpreting**

data. Throughout Investigations 3.1, 3.2, and 3.3, students measure mass and volume and calculate density. They **interpret and analyze that data**, using it to make predictions, in Investigations 3.4 and 3.5. The density column and density bottles students build in Investigations 3.4 and 3.5 also engage students in the **engineering practice of developing and using models.**

Lesson 3 addresses the **crosscutting concept** that macroscopic **patterns** are related to the nature of microscopic and atomic-level structure. Students learn that density is related to mass and arrangement of the particles that make up substances and that these characteristics are consistent from sample to sample for a given substance. Lesson 3 also addresses the **crosscutting concept of cause and effect** as students look for causal reasons that explain the behavior of materials when combined. Finally, this lesson also addresses the **crosscutting concept of scale proportion and quantity** as students use models to observe phenomena and study systems that are too small to observe and study otherwise.

of the liquids make the layers visible in the graduated cylinder. Food coloring is added to the water to make it easier to distinguish between the layers (the coloring does not significantly affect the density of the water). The copper shot (density, 8.9 g/cm³) sinks to the bottom of the column, but the nylon spacer (density, approximately 1.2 g/cm³) floats at the corn syrup/water interface because its density is greater than that of water but less than that of corn syrup.

Preparing to Teach

- Make a copy of each of the following for each student:
 - Student Sheet 3.1: *Measuring the Mass, Volume, and Density of Liquids*
 - Student Sheet 3.2: *Comparing the Densities of Different Substances*
 - Student Sheet 3.4: *Building a Density Column*
 - Student Sheet 3.5: *Building a Density Bottle*
- Make one copy of the following for each group of students:
 - Lesson Master 3.1: *Suggestions for Making a Graph of the Relationship Between Mass and Volume of Water*
- Confirm that each electronic balance is in proper working order.
- Decide on a method to distribute materials and collect them at the end of each investigation.
- Decide how you will divide the class into groups. Ideally, students will work in groups of four to perform the investigations.

Building Coherent Learning Progressions within a Lesson

Through a series of investigations in *Lesson 3: Density Makes a Difference*, students dive more deeply into understanding how density can be used to identify a substance and to predict how a substance will behave under different conditions.



Density Makes a Difference

CONNECTIONS



English
Language Arts

Getting Started
Investigation 3.1
Investigation 3.2
Investigation 3.3
Investigation 3.4
Investigation 3.5
Reflecting On What
You've Done



Science
Notebook

Getting Started
Investigation 3.1
Investigation 3.2
Investigation 3.3
Investigation 3.4
Investigation 3.5
Reflecting On What
You've Done



Mathematics

Investigation 3.2
Investigation 3.3
Investigation 3.4
Investigation 3.5

Getting Started

1. Remind students that they learned that substances have physical and chemical properties that can be used to identify them. Inform students that this lesson will focus on one physical property: density. Remind them that unless they are told otherwise, they should record observations and answers to questions in their science notebooks. Instruct them to work neatly and accurately.

2. Have students write some examples of physical and chemical properties from previous lessons in their science notebooks. Students should remember that physical properties can be measured or observed without changing the type of matter. Ask students to share their ideas with the class.

Density Makes a Difference

FOCUS QUESTION How can density be used to identify a substance and predict how it will behave under different conditions?

Introduction

Jewelry can be made of precious metals like gold, silver, and platinum. It can also be made of less expensive metals like aluminum, copper, nickel, tin, and zinc. If you wanted to test the metal composition of something, how could you do it? Would your test damage what you were testing?

With your eyes closed, do you think you could tell the difference between an object made of gold and an identical object made of copper? All substances, like gold and copper, have a property called **density** that relates their mass to their volume. In this lesson, you will examine that property more carefully. Density is a characteristic physical property of a substance. Pieces of pure gold have the same density, whether the pieces are small or large. Pieces of copper, small and large, have a different density than gold. If you measure the density of an object, you can tell if it is made of pure gold, pure copper, or something else.



Figure 3.1
Imagine you were working near a river. You found a small piece of yellow metal near the water. How could you tell if your piece of yellow metal was gold?
PHOTO: Pluglick/Shutterstock.com

Objectives for This Lesson

- ▶ Understand relationships among mass, volume, and density.
- ▶ Use mass and volume to calculate the density.
- ▶ Use models to communicate ideas about the particles within substances of varying densities.
- ▶ Use density to predict whether an object will float or sink in liquids.
- ▶ Identify unknown substances based on their density.

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STCMS™ / Matter and Its Interactions

A Systematic Approach to Building Understanding of Content and Science and Engineering Practices



Investigation 3.1

Measuring the Mass, Volume, and Density of Liquids

Materials

For you

- Science notebook
- Student Sheet 3.1: *Measuring the Mass, Volume, and Density of Liquids*
- Safety goggles

For your group

- 1 Lesson Master 3.1: *Suggestions for Making a Graph of the Relationship Between Mass and Volume of Water*
- 5 Graduated plastic cups
- 2 Calculators
- 1 Graduated cylinder
- Access to water
- Paper towels

For two groups to share

- 1 Electronic balance

For the class

- Corn syrup
- Isopropyl alcohol
- Salt brine
- Vegetable oil
- Vinegar
- Waste containers

Procedure

1. During this investigation, your class will develop the procedure all the groups will use. Record your responses in your science notebook and be prepared to share your thoughts with the class.
 - a. Why might groups of scientists want to meet to discuss procedures before investigating a research question?

- b. What are the potential advantages of working this way?
- c. What might be some potential drawbacks?

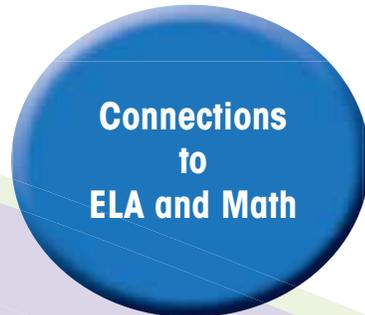
2. Together with your group, read *Building Your Knowledge: Calculating Density*. Then discuss the following questions with your group and record your responses in your science notebook:
 - a. Which properties of an object must be known in order to calculate its density?
 - b. Do you think different volumes of water will have the same density? How could you use the materials provided to investigate this?
 - c. Do you think different liquids will have the same density? How could you use the materials provided to investigate this?

Part A

3. With your group, discuss a possible procedure for determining the density of 25 mL of water using the graduated cylinder and the electronic balance. Consider the measurements and the calculations you need to make. Discuss your ideas with the class.
4. Record the steps of the agreed-upon class procedure in your student notebook.
5. Be sure to follow the methods your teacher demonstrated in *Getting Started* to obtain accurate readings using an electronic balance and a graduated cylinder.
6. Follow the class procedure to find the mass of 25 and 50 mL of water. Record your measurements in Table 1 on Student Sheet 3.1: *Measuring the Mass, Volume, and Density of Liquids*.

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Investigation 3.1: Students measure the volume and mass of a liquid to determine its density. A Building Your Knowledge reading selection, Calculating Density (see Sampler pg. 20), connects the investigation, content, and science and engineering practices.



Investigation 3.2: Students calculate the density of a regularly shaped solid by first measuring its length, width, and height to determine its volume. They use this calculation in the formula $d=m/v$ to determine the density of the object.



BUILDING YOUR KNOWLEDGE

READING SELECTION

Calculating Density

So how can you find the density of, say, a sample of pure copper?

You use the formula shown here:

density = mass divided by volume

$$d = \frac{m}{v}$$

How might you apply this formula? First, you might pick out a cube of copper with a volume of 1 cm³. Next, you use a balance to find the mass of the cube, which would turn out to be 8.96 g. Then you would insert these values into the formula for density, like this:

$$d = \frac{8.96 \text{ g}}{1 \text{ cm}^3} = 8.96 \text{ g/cm}^3$$

So, the density of copper is 8.96 grams per cubic centimeter. A gram is about the mass of a dime, so a cubic centimeter of copper has the mass of about nine dimes.

Notice that density is expressed as grams per cubic centimeter. It's important, when you compare the densities of various materials, that you use the same units for all of the materials. That's the only way you can compare their densities accurately and directly.

You measure mass by using a balance. You can measure the volume of a solid cube, or other block-shaped object, by multiplying its length, width, and height. Density is not just used to describe solids, however. Different liquids have characteristic densities as well. The volume of a liquid is measured in units called milliliters (mL). The density of a liquid is often measured in grams per milliliter or g/mL.



The density of copper is 8.96 g/cm³.
PHOTO: © Carolina Biological Supply Company

What Is a CC?

Look at the units displayed on this syringe. The same scale is used to measure the volume of liquids in milliliters (mL) or in cubic centimeters (cc or cm³). Now that you know 1 mL is equivalent to 1 cm³, you can compare the densities of solids and liquids easily.



Note the scale on this syringe. What does that imply about the relationship between milliliters and cubic centimeters?
PHOTO: BIONANIMATE/istock.com

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Investigation 3.3

Measuring the Densities of Irregular Objects

Materials

For you

- Science notebook
- Safety goggles

For your group

- 2 Calculators
- 1 Aluminum cylinder
- 1 Graduated cylinder
- 1 Nylon spacer
- 1 Steel bolt
- Access to water
- Paper towels

For two groups to share

- 1 Electronic balance

Procedure

1. In the previous investigation, you determined the densities of different, regularly shaped solids. In this investigation, you will determine the density of some objects with complex, irregular shapes. Observe the steel bolt, aluminum cylinder, and nylon spacer. Discuss with your group how you could determine the mass and volume of each of these objects. How could you calculate their densities? Be prepared to discuss your group's ideas with the class.
2. As a class, develop a plan that uses the materials provided to determine the density of an irregular object. Once the class has agreed on a plan, record the class procedure in your science notebook.

3. Draw a series of simple diagrams in your student notebook to show how you are going to find out the mass and volume of irregular objects in this investigation.
4. Work with your group to design a data table for this investigation in your science notebook. Make sure you include space in the table for all your measurements, your calculations, and the densities of the objects. Use the correct units of measure when labeling columns.
5. Ask your teacher for approval of your diagrams and data table.
6. Complete your data table. You may be asked to share your results with the class.
7. Read *Building Your Knowledge: Why Bother with Density?* In your own words, ask: Why is it important to compare the densities of substances at the same temperature? Record your response in your science notebook.
8. Discuss the following questions with your group and record your responses in your science notebook:
 - a. Are any of the blocks from Investigation 3.2 or objects in this investigation made from the same substance? What evidence do you have for your answer?
 - b. How do the densities of the objects compare with the density of water? How do they compare with the density of other liquids you measured in this lesson?

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Investigation 3.3: Students use the skills and knowledge gained in the previous investigation to determine the density of an irregularly shaped object.

Math
Connection
MP5

Investigation 3.4: Students design a density column based on their data from the previous investigations.

Developing
and
Using Models

Investigation 3.4

Building a Density Column

Materials

For you

- Science notebook
- 1 Student Sheet 3.4: *Building a Density Column*
- Safety goggles

For your group

- 4 Graduated plastic cups
- 1 Aluminum cylinder
- 1 Jar of beads
- 1 Nylon spacer
- 1 Plastic cylinder
- Paper towels

For the class

- Colored water
- Corn syrup
- Isopropyl alcohol
- Vegetable oil
- Waste containers

Procedure

1. In previous investigations, you calculated the density of different objects. In this investigation, you will use the data you collected during different investigations to predict the appearance of different objects when they are combined.
2. Real-life scientists may be required to analyze data collected over a long period of time. They use data collected in their notebooks to prepare for future experiments. Look carefully at Tables 1 and 2 on Student Sheet 3.4: *Building a Density Column*. During previous investigations in this lesson, you collected the data you will use to complete these tables.

3. Look back on the data you collected in Investigation 3.1 and use it to fill in Table 1 on your student sheet.
4. Look carefully at the densities you have calculated. What do you predict will happen when you mix the vegetable oil, corn syrup, and water in the plastic cylinder? Record and explain your prediction in your science notebook, and include a labeled diagram to show what you think the liquids will look like when they are allowed to settle.
5. Use a graduated plastic cup to obtain 25 mL of each liquid in Table 1. (The colored water has the same density as water.)
6. Pour the 25 mL of corn syrup into the plastic cylinder. Next, add 25 mL of vegetable oil. Finally, add 25 mL of colored water and allow the contents of the plastic cylinder to settle.
7. Draw a labeled diagram in your science notebook to show the appearance of the liquids after they have settled.
8. Discuss the following questions with your group and record your responses in your science notebook.
 - a. Do the liquids mix together (are miscible) or form distinct layers (are immiscible)?
 - b. What is the relationship between the density of the liquid and its position in the density column?

continued

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Build content knowledge by connecting math and English language arts directly to students' investigative experiences.

BUILDING YOUR KNOWLEDGE

READING SE

Calculating Density

So how can you find the density of, say, a sample of pure copper?

You use the formula shown here:

density = mass divided by volume

$$d = \frac{m}{v}$$

How might you apply this formula? First, you might pick out a cube of copper with a volume of 1 cm³. Next, you use a balance to find the mass of the cube, which would turn out to be 8.96 g. Then you would insert these values into the formula for density, like this:

$$d = \frac{8.96 \text{ g}}{1 \text{ cm}^3} = 8.96 \text{ g/cm}^3$$

So, the density of copper is 8.96 grams per cubic centimeter. A gram is about the mass of a dime, so a cubic centimeter of copper has the mass of about nine dimes.

Notice that density is expressed as grams per cubic centimeter. It's important, when you compare the densities of various materials, that you use the same units for all of the materials. That's the only way you can compare their densities accurately and directly.

You measure mass by using a balance. You can measure the volume of a solid cube, or other block-shaped object, by multiplying its length, width, and height. Density is not just used to describe solids, however. Different liquids have characteristic densities as well. The volume of a liquid is measured in units called milliliters (mL). The density of a liquid is often measured in grams per milliliter or g/mL. ■



The density of copper is 8.96 g/cm³.

PHOTO: © Carolina Biological Supply Company

What Is a CC?

Look at the units displayed on this syringe. The same scale is used to measure the volume of liquids in milliliters (mL) or in cubic centimeters (cc or cm³). Now that you know 1 mL is equivalent to 1 cm³, you can compare the densities of solids and liquids easily.



Note the scale on this syringe. What does that imply about the relationship between milliliters and cubic centimeters?

PHOTO: BOONJAEM/Shutterstock.com

ELA
Connection
RST.6-8.10

Three-Dimensional Application

Investigation 3.5: Students combine skills, knowledge, and data to engineer a density bottle that contains two different liquids and two different solids on based on observations and analysis of data collected in previous Lesson 3 investigations.

**ELA
Connection
RST.6-8.3**

Investigation 3.5: Building a Density Bottle

Procedure

1. Inform students that they will apply what they have learned about density to design a density bottle similar to the one they used in the pre-assessment activity. Review Investigation 1.6: Beads in a Bottle, which relates directly to this investigation. Show students the bottle containing beads (prepared for Investigation 1.6). Ask students

to share how their understanding of the substances in this bottle has changed since the pre-assessment.

2. Have students review the data they collected in Investigation 2.6. Students should remember that the two colors of beads formed two distinct layers, with the UV beads floating above the green beads.

From this, students should deduce that the UV beads are less dense than the green beads.

3. Have students review the data they collected during Investigation 3.1, and use it to fill in Table 1 on Student Sheet: 3.5: *Building a Density Bottle*. Students may have enough information to deduce the two liquids used to make the bottle they used in Investigation 1.6.

4. Have students obtain 30 mL samples of any liquid they think you may have used. If you are unsure about which liquids to test, you may allow them to test all liquids, or all colorless liquids. Students should place one green and one UV bead in each liquid they are testing. Watch for floating green beads in the cup containing water. Students should knock the bubbles off the green beads before recording information.

5. Students should record their predictions in their science notebooks.

Investigation 3.5

Building a Density Bottle

Materials

For your teacher

- Bottle containing beads

For you

- Science notebook
- 1 Student Sheet 3.5: *Building a Density Bottle*
- Safety goggles

For your group

- 6 Graduated plastic cups
- 1 Jar of beads
- 1 Plastic bottle
- Access to water
- Paper towels

For two groups to share

- 1 Electronic balance

For the class

- Containers for used liquids
- Corn syrup
- Isopropyl alcohol
- Saltwater brine
- Vegetable oil
- Vinegar
- Water

Procedure

1. In the previous investigation, you made predictions about the appearance of different substances when they are combined. In this investigation, you apply what you have learned about density to design a density bottle similar to the one you used in the pre-assessment activity. (See Figure 3.5.) Look back at your observations from Investigation 1.6: Beads in a Bottle. How has your understanding of the substances in this bottle changed since then? Discuss your answer with the class.

2. Look back on the data you collected in Investigation 1.6: Beads in a Bottle. What does the data you collected tell you about the density of each type of bead?

3. Look back on the data you collected during Investigation 3.1, and use it to fill in Table 1 on Student Sheet 3.5: *Building a Density Bottle*. Your teacher used two of the liquids from Investigation 3.1 to create the bottle you used in the pre-assessment. Do you have enough information to determine what liquids your teacher used? Why or why not?

4. Use the graduated cups to obtain 30-mL samples of each liquid you think your teacher may have used. Place one green and one UV bead in each cup and record your observations in Table 1. (Check to ensure that no beads have air bubbles attached to them.)

continued



Figure 3.5
What liquids do you think your teacher used to create this bottle?

PHOTO: © Carolina Biological Supply Company

continued

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Lesson 3
Density Makes a Difference

Investigation 3.5: Building a Density Bottle *continued*

6–7. Check student drawings. Students should show two bottles, one before it is shaken and one after. Students should show two liquids in the unshaken bottle with beads in the center. The second bottle should show UV beads at the top and green beads at the bottom separated by a liquid mixture.

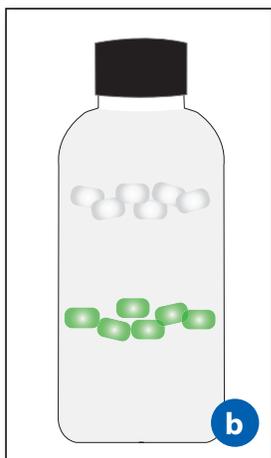
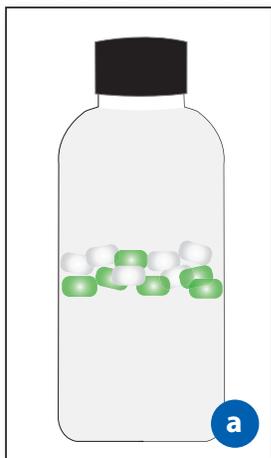


Figure 3.2
Sample student diagrams
(a) before shaking, and
(b) after shaking

8. Allow students to evaluate their predictions by placing 5 green and 5 UV beads in the plastic bottle. Students should add 30 mL of the liquids they recorded as predictions, and secure the cap on the bottle.

9. Students should test their design by shaking it two times and observing. If the bottle is designed correctly, their observations will

match those that they recorded for Investigation 1.6.

10. Students should write a paragraph describing their findings during this investigation.

EXIT SLIP

Illustrations and diagrams can be helpful for communicating ideas because they can represent complex ideas and explanations in a visual way.

Investigation 3.5 *continued*

- Use the data you collected in Table 1 to predict which two liquids your teacher used to make the density bottle in the pre-assessment. Record your prediction in your science notebook.
- The green beads have a density of 1.05 g/cm^3 and the UV beads have a density of 0.8 g/cm^3 . A photograph of the density bottle is shown in Figure 3.5. Draw a diagram similar to the photograph in your science notebook. Label your diagram with the density of each type of bead and each liquid you plan to place in the bottle.
- Draw a diagram in your science notebook that models the behavior you would expect of the liquids and beads inside the density bottle after it is shaken. In a paragraph below your diagram, describe what you think will happen and why.
- Evaluate your prediction by placing five green and five UV beads in the bottle. Add 30 mL of the two liquids you think your teacher used. Secure the cap on the bottle.
- Test your design by shaking the bottle two times and observing it for one minute. Record your observations in your science notebook. Do these observations match those you recorded in Investigation 1.6?
- Follow your teacher's instructions for cleanup and disposal of liquids.
- Write a paragraph that describes the findings of your investigation. Were you able to determine which liquids your teacher used to create the bottle you used in the pre-assessment? If additional time and materials were available, what additional investigations could you carry out that would make you certain about the contents of the density bottle?

EXIT SLIP

How can illustrations and diagrams be helpful for communicating ideas?



Reflecting On What You've Done

1. Students should make a claim about the floating behavior of a helium balloon in air. Helium-filled balloons float in air. The volume of helium that fills them must have less mass than the same volume of air, which means helium must be less dense than air.

2. Have students read Extending Your Knowledge: *Archimedes's*

Crowning Moment. If you wish, share that Archimedes (c.290 BCE–c.211 BCE) was a mathematician, engineer, and inventor in ancient Greece. Archimedes's principle describes the physical law of buoyancy, which states that an object submerged in a fluid is acted upon by an upward force equal in magnitude to the

weight (the downward gravitational force on the mass) of the fluid displaced by the object. Archimedes's observations about displacement provide a method to determine the volume of an irregularly shaped object and enable the determination of density.

continued



REFLECTING

ON WHAT YOU'VE DONE

1. At a party, you might observe brightly colored, helium-filled balloons rising to a room's ceiling. From this observation and what you have learned in this lesson, what can you claim about the densities of air and helium? Discuss your claim with your group, using reasoning that supports your claim.
2. Read Extending Your Knowledge: *Archimedes's Crowning Moment*. Record your responses to the discussion questions in your science notebook and prepare to share your thoughts in a class discussion.
3. Look at the picture of salad dressing in Figure 3.6. The density of olive oil is 0.92 g/mL. The density of vinegar is 1.02 g/mL. Draw a diagram to model the particles in each liquid in the dressing. Imagine you poured liquid from the container without shaking it first. Which liquid would you pour on your salad?
4. Imagine that you mixed the salad dressing in Figure 3.6 by shaking it. Draw a model of the particles in the mixed salad dressing. What properties of the mixed salad dressing would differ from the properties of the separated salad dressing?



Figure 3.6
This simple salad dressing contains olive oil and vinegar.
PHOTO: © Carolina Biological Supply Company

EXIT SLIP

How can density be used to identify a substance and predict how it will behave under different conditions?

Lesson 3 / Density Makes a Difference

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EXIT SLIP

The density of a substance is a characteristic property. If the density of two substances is the same, they might be the same substance. Density can also be used to predict if a solid object will sink or float, or if an immiscible liquid will be layered above or below another liquid.

What to look for:

Students should understand that density is a characteristic property and that it can be used to predict layering, floating, and sinking.

Exit slips check for understanding and the ability to explain phenomena.

Lesson 3 **Density Makes a Difference**

Reflecting On What You've Done *continued*

3. Students should make connections between the salad dressing in Figure 3.3 and their experiences with the density column and density bottle. Students should draw a diagram to model the particles in each liquid in the salad dressing. In this model, the oil particles are in the top of the container. If a student poured this bottle, they would pour only oil on their salad.

4. Students should draw a diagram to model mixed particles when the salad dressing bottle is shaken. The appearance of the mixed salad dressing would differ from the separated salad dressing.

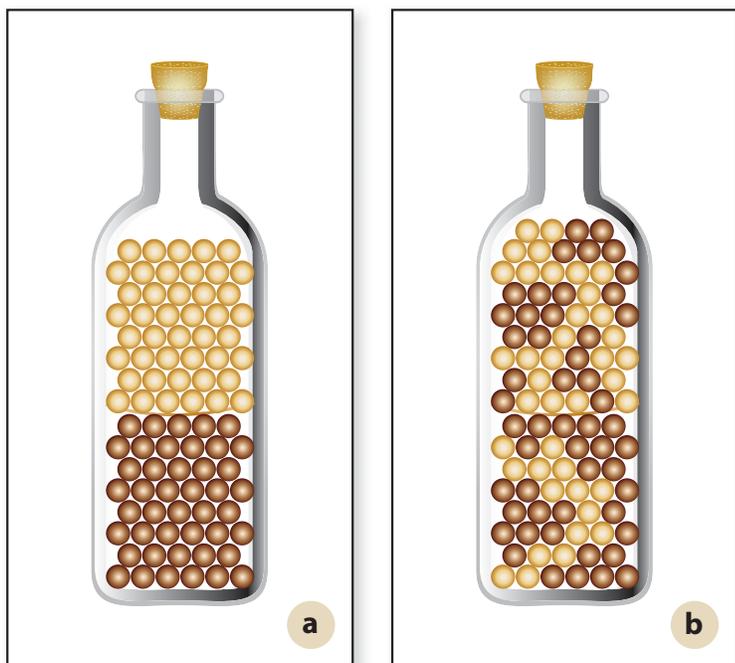


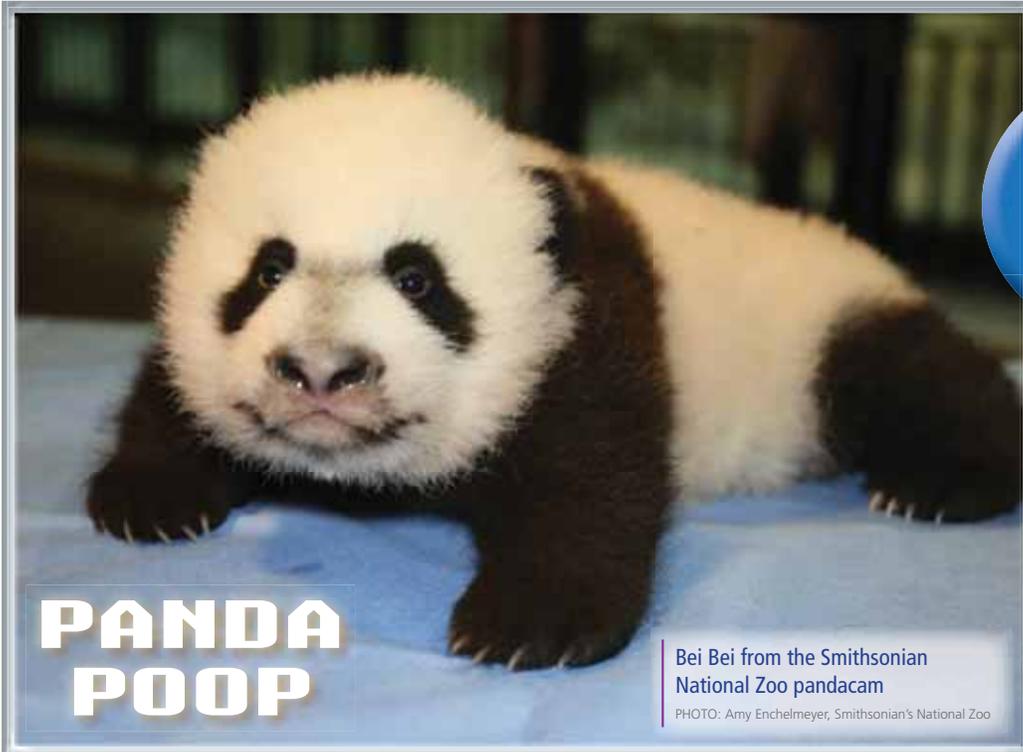
Figure 3.3
Sample student diagrams (a) before shaking, and (b) after shaking

Non-Fiction Literacy with Real-World Applications

Non-fiction literacy features real-world phenomena and applications connected to students' investigative learning experiences.

EXTENDING YOUR KNOWLEDGE

READING SELECTION



PANDA POOP

Bei Bei from the Smithsonian National Zoo pandacam

PHOTO: Amy Enchelmeyer, Smithsonian's National Zoo

ELA
Connection
RST.6-8.10



Ninety-nine percent of a panda's diet is bamboo. This passes through them very quickly, so panda poop looks wood-like.

PHOTO: Stacey Tabellario, Smithsonian's National Zoo

Now that I have your attention, let's talk about how scientists use density to separate things!

Bei Bei, the Smithsonian National Zoological Park's latest panda cub, is very cute. Sadly, cute panda cubs are not that common. As you are probably aware, pandas are an endangered species. Fewer than 1,600 remain in the wild. One reason for this is that the period when a female panda is able to mate is very short. Female pandas are fertile for just one day a year. Male pandas also have weak back legs, which makes it hard for them to mate successfully. In short, getting pregnant if you are a panda is not easy! Pandas need help from scientists.

When female pandas are fertile, levels of chemicals in their body called hormones change. The main female reproductive hormone is called estrogen. When a panda is fertile, her estrogen level rises. The level of estrogen can be measured by analyzing—you have guessed it—poop! Why poop? you might ask. Poop is easier to collect than blood and urine. It is usually solid, and because pandas poop a lot, plenty of it is available. Fortunately, panda poop isn't that smelly. In fact, it has been described as smelling like green tea!

Once the poop has been collected, it is transferred to a laboratory. In the laboratory, it is first dried to remove the water. Water makes up 75 percent of poop and is removed because it doesn't contain anything of interest to the scientists. The dry poop is then crushed into a powder. Any large pieces of undigested bamboo are removed using a sieve. What is left is put into test tubes and a mixture of alcohol and water is added. The tubes are shaken to mix everything thoroughly. This helps the hormones in the sample dissolve in the alcohol.



A special machine called a vortex mixer is used to shake the sample.

PHOTO: © Carolina Biological Supply Company



A centrifuge can spin several samples at the same time.

PHOTO: Science Photo Library/Shutterstock.com

The mixed sample is then put into a machine called a centrifuge. This is where density comes in. A centrifuge looks a little like a top-loading washing machine. It spins the samples at very high speed. Spinning at high speed creates a centrifugal force. This causes the denser materials to sink more rapidly than they would under gravity. Centrifuging allows scientists to separate materials with a similar density. Under gravity, these materials would take a long time to separate. Centrifuging speeds the process up.

In the centrifuge, the alcohol separates from the rest of the poop sample. The alcohol containing the hormones is less dense than the rest of the sample and rises to the top of the test tube. It can then be removed using



Scientists often use density to separate substances that are soluble in one liquid, but not the other.

PHOTO: © Carolina Biological Supply Company



The estrogen level is found by measuring color intensity.

PHOTO: © Carolina Biological Supply Company

a pipet. Finally, the alcohol is evaporated, leaving just the hormones.

Now that the hormones have been isolated, the level needs to be measured. This requires adding another chemical that reacts with the hormones and changes their color. The deeper the color, the higher is the level of hormones. The intensity of the color is measured by a machine called a spectrophotometer. The results are compared to previous samples. If the level of estrogen is higher than usual, Smithsonian Zoo staff know the panda is ready to mate.

Who knew that panda poop could be so useful? Scientists use it to make panda babies! ■

Discussion Question

1. Why do you think that a mixture of water and alcohol is added to the sample after it has been dried and crushed?



Scientists have helped the Smithsonian National Zoo's female panda, Mei Xiang, have three successful births.

PHOTO: Abby Wood, Smithsonian's National Zoo

Summative Assessment

STCMS summative assessments target the full range of unit concepts and practices through a performance assessment and a written assessment.

Lesson 11: Assessment: *Matter and Its Interactions*: Students apply the knowledge and skills they have developed over the course of the unit to design a cold pack for a manufacturing company.



Assessment: Matter and Its Interactions

CONNECTIONS



Getting Started
Performance Assessment
Written Assessment
Reflecting On What You've Done



Getting Started
Performance Assessment
Reflecting On What You've Done



Performance Assessment
Performance Assessment
Written Assessment



Getting Started
Performance Assessment

Getting Started

1–2. Facilitate a class review session and open the floor to questions about all topics covered in the unit. Students may wish to review prior investigations, student sheets, or reading selections.

3. If this will be the students' first experience with a Performance Assessment, give them some background information about its purpose and format. (See Tab 4 for more information.) Call on volunteers to identify and describe



Assessment: Matter and Its Interactions



FOCUS QUESTION How can we use our knowledge of matter and its interactions to solve problems?

Introduction

In this unit, you explored the physical and chemical properties of matter and how these properties are related to how atoms and molecules interact. Some of the key topics included atomic and molecular structures, physical and chemical interactions, the role energy plays in chemical processes, conservation of matter, and the synthesis of new substances.

In Lesson 8, you dissolved a chemical compound to make a design a solution for heat on demand. In this lesson, you will draw on your skills and knowledge to design a cold pack. You will also answer written questions about matter and its interactions to further demonstrate what you have learned throughout this unit.



Figure 11.1
Low temperatures can reduce blood flow to an injury. When a cold pack is applied, it can reduce pain and swelling at the site of the injury.

PHOTO: Andrey_Popov/Shutterstock.com



Objectives for This Lesson

- ▶ Review concepts from the Matter and Its Interactions unit.
- ▶ Complete a performance assessment by constructing explanations and designing a solution.
- ▶ Make predictions about chemical compounds and use evidence to support your predictions.
- ▶ Apply your knowledge and skills to answer questions in a written assessment about concepts related to matter and its interactions.
- ▶ Update your concept map with your new knowledge and apply what you have learned to your daily life.

How Are They Progressing Against the Next Generation Science Standards?

Unit-specific rubrics to assess three-dimensional learning guide evaluation of student proficiency with the Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas addressed in the specific unit.

Appendix E: Assessing Three-Dimensional Learning

Science and Engineering Practices			
Criterion	1. Beginning	2. Developing	3. Proficient
Asking Questions and Defining Problems	Student cannot define a design problem that can be solved through the development of an object, tool, process, or system.	Student can partially define a design problem that can be solved through the development of an object, tool, process, or system.	Student can define a design problem that can be solved through the development of an object, tool, process, or system.
	Student cannot identify multiple criteria or constraints that may limit possible solutions.	Student can partially identify multiple criteria or constraints that may limit possible solutions.	Student can identify multiple criteria or constraints that may limit possible solutions.

Crosscutting Concepts			
Criterion	1. Beginning	2. Developing	3. Proficient
Patterns	Student rarely recognizes that macroscopic patterns are related to the nature of microscopic and atomic-level structure.	Student occasionally recognizes that macroscopic patterns are related to the nature of microscopic and atomic-level structure.	Student frequently recognizes that macroscopic patterns are related to the nature of microscopic and atomic-level structure.
	Cause and Effect	Student rarely uses cause-and-effect relationships to predict phenomena in natural or designed systems.	Student occasionally uses cause-and-effect relationships to predict phenomena in natural or designed systems.
Scale, Proportion, and Quantity	Student rarely explains that	Student occasionally explains	Student frequently explains

Disciplinary Core Ideas			
Criterion	1. Beginning	2. Developing	3. Proficient
PS1.A: Structure and Properties of Matter	Student cannot explain that substances are made from different types of atoms, which combine with one another in various ways.	Student can partially explain that substances are made from different types of atoms, which combine with one another in various ways.	Student can explain that substances are made from different types of atoms, which combine with one another in various ways.
	Student cannot explain that atoms form molecules that range in size from two to thousands of atoms.	Student can partially explain that atoms form molecules that range in size from two to thousands of atoms.	Student can explain that atoms form molecules that range in size from two to thousands of atoms.
	Student cannot explain that each pure substance has characteristic physical and chemical properties that can be used to identify it.	Student can partially explain that each pure substance has characteristic physical and chemical properties that can be used to identify it.	Student can explain that each pure substance has characteristic physical and chemical properties that can be used to identify it.
	Student cannot explain that gases and liquids are made of molecules or inert atoms that are moving about relative to each other.	Student can partially explain that gases and liquids are made of molecules or inert atoms that are moving about relative to each other.	Student can explain that gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
	Student cannot explain that the molecules in a liquid are constantly in contact with others.	Student can partially explain that the molecules in a liquid are constantly in contact with others.	Student can explain that the molecules in a liquid are constantly in contact with others.
	Student cannot explain that the molecules in a gas are widely spaced except when they happen to collide.	Student can partially explain that the molecules in a gas are widely spaced except when they happen to collide.	Student can explain that the molecules in a gas are widely spaced except when they happen to collide.
	Student cannot explain that atoms in a solid are closely spaced and may vibrate in position but do not change relative locations.	Student can partially explain that atoms in a solid are closely spaced and may vibrate in position but do not change relative locations.	Student can explain that atoms in a solid are closely spaced and may vibrate in position but do not change relative locations.

Is It Really an NGSS Program?

7-Point NGSS Program Checklist—A Quick-Start Guide

Five Innovations of NGSS	Questions
Three-Dimensional Construction	<ul style="list-style-type: none"> • Does the curriculum explicitly reflect and integrate all three dimensions of the NGSS and build to the Performance Expectations? • Are there multiple opportunities for students to master each dimension?
Focus on Engaging Phenomena	<ul style="list-style-type: none"> • Are students observing, investigating, modeling, and explaining phenomena? • Are they conducting inquiry science investigations and designing solutions? • Are they engaging?
Engineering Design and the Nature of Science	<ul style="list-style-type: none"> • Are engineering standards and science standards taught with equal importance? • Do learning experiences include Disciplinary Core Ideas of engineering design as well as the Science and Engineering Practices and Crosscutting Concepts of both engineering and the nature of science? • Are engineering design and the nature of science integrated throughout the science content and not separate lessons at the unit's end?
Coherent Learning Progression	<ul style="list-style-type: none"> • Is it clear that there is a coherent learning progression within each unit as well as across grade levels? • Is there a convincing concept storyline or other coherent framework? • Do units build on and extend knowledge and understanding gained in prior grades?
Connections to Math and ELA	<ul style="list-style-type: none"> • Are connections to the Mathematics and ELA Standards explicit?
Key Support Materials	
Materials	<ul style="list-style-type: none"> • Do students have the materials to carry out scientific investigations and engineering design projects?
Assessment	<ul style="list-style-type: none"> • Are there multiple assessments capable of evaluating student progress and the performance expectations, including the science and engineering practices?

So many programs claim to meet the NGSS, but how can you be sure? Use this 7-point NGSS program checklist as a guide.

STCMS™	Where Is It in STCMS?	
 Yes	<ul style="list-style-type: none"> • Unit Overview lesson summaries show how Performance Expectations build over time • Alignment to Next Generation Science Standards before each lesson explicitly describes the integration of the Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices • Lessons that integrate real-world situations with scientific principles, leading to engaging and relevant instruction 	
 Yes	<ul style="list-style-type: none"> • Focus Questions for each lesson that look at phenomena from a science perspective • Introductions that provide students with examples of phenomena that they can relate to • Investigations that: <ul style="list-style-type: none"> • give students multiple opportunities to study, model, and explain phenomena • provoke questions and call for the design of solutions 	
 Yes	<ul style="list-style-type: none"> • Lesson at a Glance Alignment to Next Generation Science Standards • Lessons build an understanding of science and the world while incorporating meaningful engineering design opportunities • Lessons build an understanding of science content and develop use of evidence to revise design solutions 	
 Yes	<ul style="list-style-type: none"> • Unit Concept Storylines show at a glance the conceptual progression over the course of the unit • Unit Table of Contents shows the focus on investigations and phenomena and on nonfiction support • STCMS Learning Framework illustrates the progression of concepts across grade levels and strands • Lessons that provide multiple opportunities for students to engage prior knowledge and experience investigative phenomena to deepen understanding and provide explanations 	
 Yes	<ul style="list-style-type: none"> • Lesson at a Glance correlates ELA and Mathematics Standards for each lesson • Reading Selections that include discussion questions intentionally constructed to support ELA Standards • Teacher Edition includes explicit guidance on the importance of and the “how to” of connecting science and the Mathematics and ELA standards (Tab 3) 	
 Yes	<ul style="list-style-type: none"> • Unit purchase includes the Teacher Edition, Student Editions—both with digital access—and all the materials to complete the investigations that are not commonly found in middle school science labs/classrooms. 	
 Yes	<ul style="list-style-type: none"> • A coherent system of classroom-based assessments that provide powerful information to inform teaching and learning, for not only the teacher, but the student as well. STCMS units include: <ul style="list-style-type: none"> • pre-assessment lesson • formative assessment including Exit Slips to monitor student progress • self-assessment for students • summative assessment—performance and written components • unit-specific NGSS rubrics to assess three-dimensional learning 	

Learning Framework

Life Science

Ecosystems and Their Interactions

LS1-5, LS1-6, LS2-1, LS2-2, LS2-3, LS2-4, LS2-5, LS4-4, LS4-6, ESS3-3, ETS1-1, ETS1-2

Structure and Function

LS1-1, LS1-2, LS1-3, LS1-6, LS1-7, LS1-8, LS4-2, LS4-3

Genes and Molecular Machines

LS1-1, LS1-4, LS3-1, LS3-2, LS4-4, LS4-5, LS4-6

Earth/Space Science

Weather and Climate Systems

ESS2-4, ESS2-5, ESS2-6, ESS3-2, ESS3-4, ESS3-5, PS3-4, ETS1-1, ETS1-2

Earth's Dynamic Systems

LS4-1, ESS1-4, ESS2-1, ESS2-2, ESS2-3, ESS3-1, ESS3-2, ETS1-1, ETS1-2, ETS1-3, ETS1-4

Space Systems Exploration

PS2-4, ESS1-1, ESS1-2, ESS1-3, ETS1-1, ETS1-2

Physical Science

Energy, Forces, and Motion

PS2-1, PS2-2, PS2-3, PS2-5, PS3-1, PS3-2, PS3-5, ETS1-1, ETS1-2, ETS1-3, ETS1-4

Matter and Its Interactions

PS1-1, PS1-2, PS1-3, PS1-4, PS1-5, PS1-6, PS3-4, ETS1-1, ETS1-2, ETS1-3, ETS1-4

Electricity, Waves, and Information Transfer

LS1-8, PS2-3, PS2-5, PS3-3, PS3-4, PS3-5, PS4-1, PS4-2, PS4-3, ETS1-1, ETS1-2, ETS1-3, ETS1-4

Units for Grades 6—8

Three-dimensional learning for middle school

For more information,
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