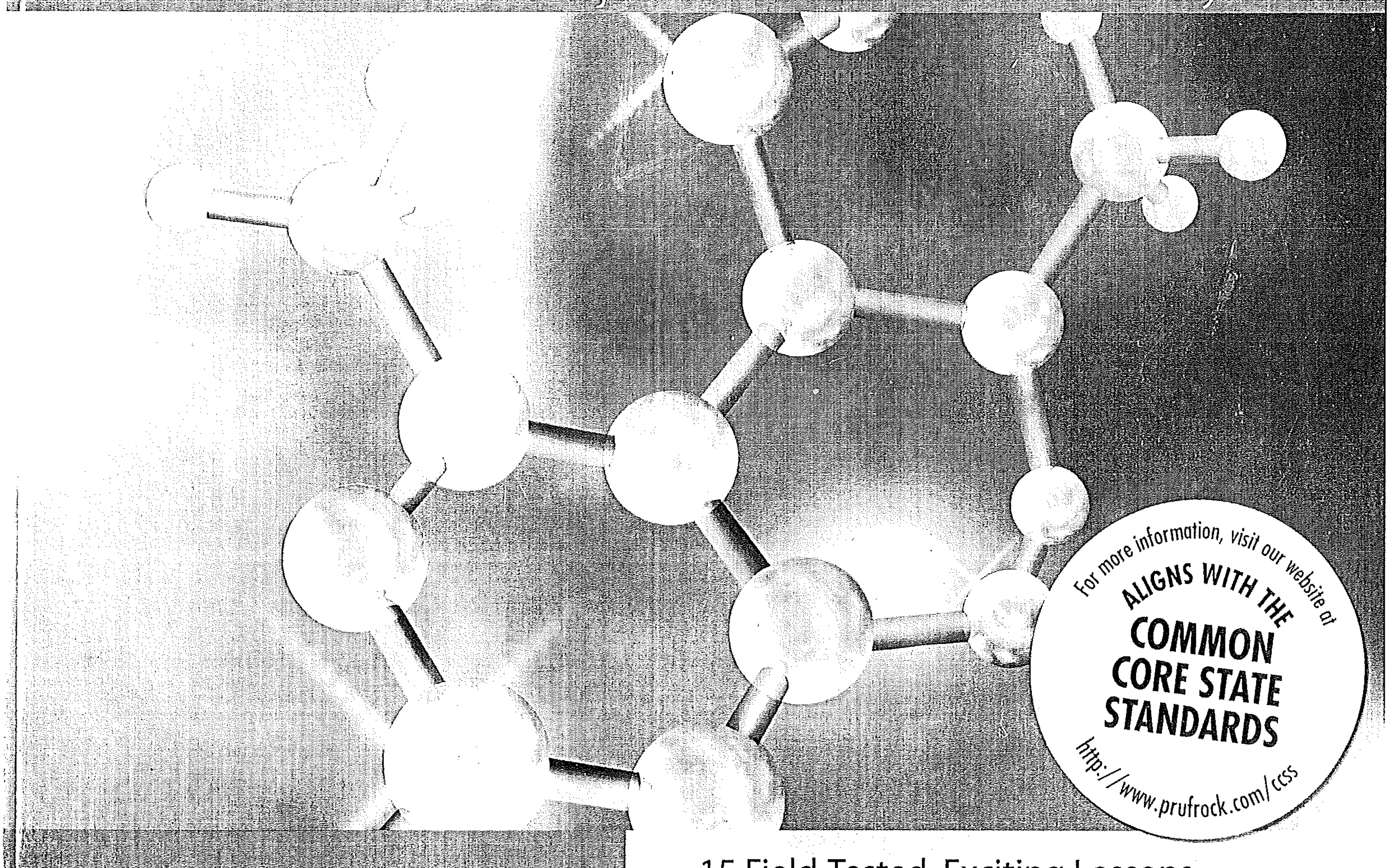
a physical science unit for high-ability learners in grades 2–3

# What's the Matter?

Project Clarion Science Unit for Primary Grades




- 15 Field-Tested, Exciting Lessons
- Hands-On Exploration of Matter
- Inquiry-Based Approach to Studying Science
- Higher Level Thinking Challenges

The College of William & Mary's
Center for Gifted Education

# Introduction to the Unit

The Project Clarion Science Units for Primary Grades are designed to introduce young students to science concepts and science processes. These units utilize a hands-on, constructivist approach that allows children to build their knowledge base and their skills as they explore science topics through play and planned investigations. Students are engaged in creative and critical thinking, problem finding and solving, process skill development, and communication opportunities. Each individual unit is designed to strengthen essential concepts such as quantity, direction, position, comparison, colors, letter identification, numbers, counting, size, social awareness, texture, material, shape, time, and sequence. The Project Clarion Science Units for Primary Grades also focus on overarching concepts such as systems, change, and cause and effect.

*What's the Matter?* is a physical science unit for high-ability learners in grades 2–3 that focuses on the properties of solids, liquids, gases, and the processes by which matter changes states. In this unit, students work on problem-solving scenarios that utilize their new knowledge of matter, change in physical properties, and the measurement of matter—all while preparing a presentation to share new ideas and discoveries about matter in a classroom Matter Conference. The overarching concept of *change* is incorporated within the lessons to deepen students' understanding of the scientific concepts in this unit.

## Essential Understandings of the Unit

Through completion of this unit, the student will convey the following essential understandings:

- All common substances are made of matter.
- Matter is anything that has mass and takes up space.
- There are three main states of matter: solids, liquids, and gases.
- Objects can be described by color, shape, texture, relative size and weight, and position.
- Matter can change from one state to another; these changes are referred to as physical changes.
- Volume is the measure of the amount of space occupied by matter.
- Mass is a measure of the amount of matter.
- Materials are composed of parts that are too small to see without magnification.
- Physical properties remain the same when a material is reduced in size.
- Some liquids separate when mixed with water.
- Some solids will dissolve in water, and more quickly in hot than cold water.
- Temperature and energy can create physical changes in matter.

Before you begin, you may choose to use the preteaching lesson on safety in the science classroom, Science Safety (pp. 23–26). Simulating the work of real scientists, students develop a systematic set of inquiry skills. As scientists, students must learn the basic safety precautions that are necessary while performing experiments of different nature. Science safety is outlined in a brief lesson that is located prior to the preassessment lesson. This optional lesson is designed to outline the science safety rules in this unit, as well as to instill in students the importance of safety in the classroom. Science safety guidelines for teachers also are provided in this lesson.

## Scientific Investigation and Reasoning

The Wheel of Scientific Investigation and Reasoning contains the specific processes involved in scientific inquiry that guide students' thinking and actions. To read more about these processes and suggestions for implementing the wheel into this unit's lessons, see Appendix A: Teaching Models (pp. 141–151).

The following lessons heavily utilize the Wheel of Scientific Investigation and Reasoning: Lesson 2 helps students to gain a better understanding of what scientists do; Lesson 4 introduces the wheel, including the six components of scientific investigation; and Lesson 5 continues the introduction to scientific investigation by requiring students to make observations, ask questions, learn more about the topic, design and conduct experiments, and share their results.

Students apply the components of scientific investigation throughout this unit by using the wheel to analyze aspects of an investigation and for planning investigations. Concepts of scientific reasoning and investigation within the lessons include:

- To make observations, scientists use their senses, as well as instruments, to note details, identify similarities and differences, and record changes in phenomena.
- Observations about familiar objects or events often lead to the development of important questions that can spark further investigation.
- Investigation requires a careful review of what is known and what additional information must be sought.
- An experiment is a fair test designed to answer a question.
- Scientific investigations require careful gathering and analysis of data.
- To communicate findings, one must provide a clear description of what question was asked, what prediction was made, what experiment was conducted, what data were collected and analyzed, and what conclusions and inferences were developed.

## Concepts Covered in This Unit

Many teachers find concept mapping useful for envisioning the scope of a lesson or unit. Teachers also use student-developed concept maps as a way of measuring student progress. Each Project Clarion unit contains an overview concept map (see Figure 1) that displays the essential knowledge included in the lessons and the connections students should be able to make as a result of their experiences within the unit. This overview may be useful as a classroom poster that teachers and students can refer to throughout the unit.

Practice in using concept maps supports students' learning as they begin to build upon known concepts. Students begin to add new concepts to their initial understanding of a topic and to make new connections between concepts. The use of concept maps within the lessons also helps teachers to recognize students' conceptual frameworks so that instruction can be adapted as necessary. More information on strategies for using concept mapping, as well as a list of concept mapping practice activities, are provided in Appendix A: Teaching Models.

### *Overarching Concept*

The overarching concept for this unit is *change*. The natural world changes continually; however, some changes may be too slow to observe. Students will begin to understand the concept of change in science by learning about natural changes that occur over time, as well as manmade changes that impact conditions. Change

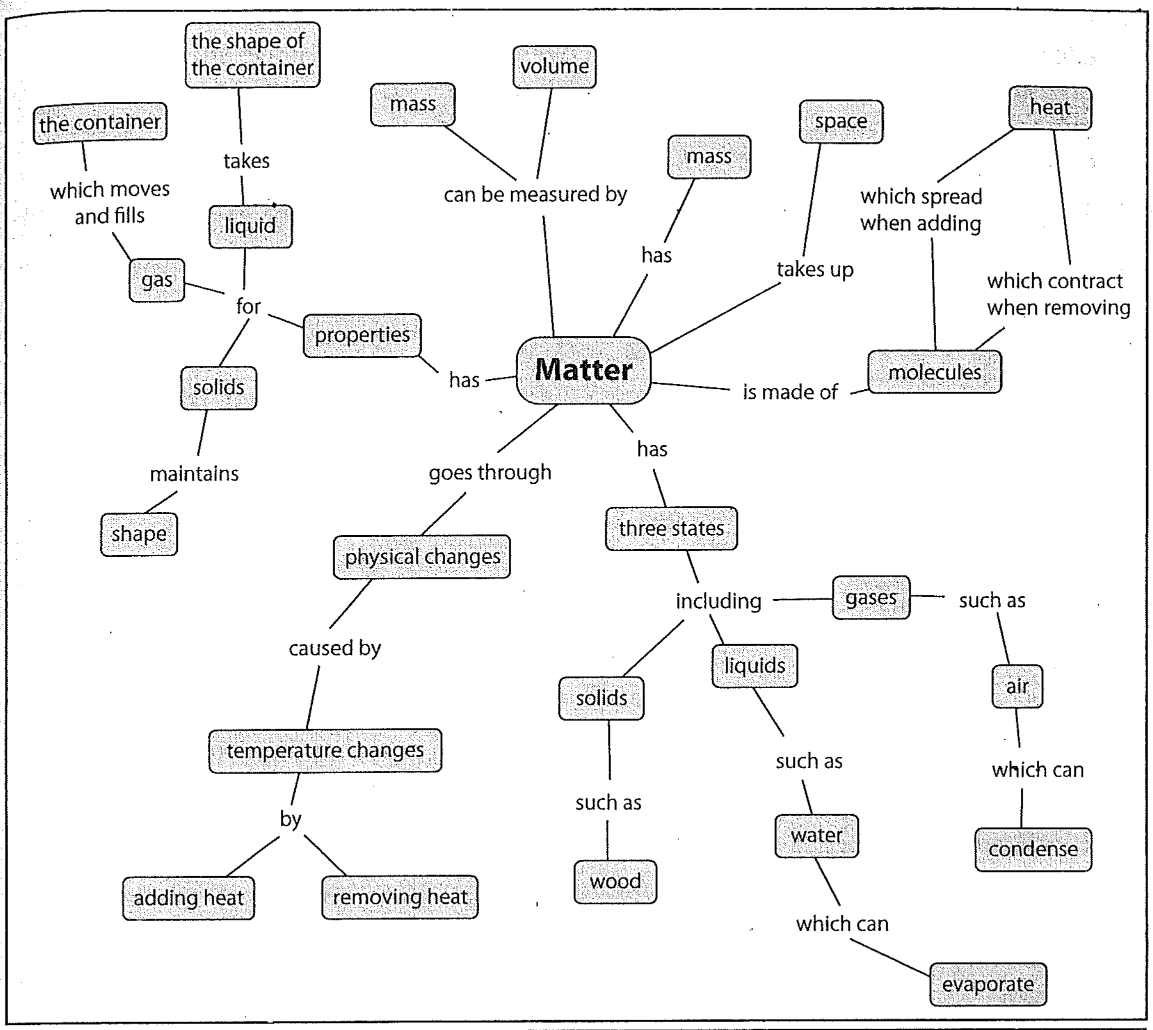



**Figure 1.** Unit concept map for *What's the Matter?*

was chosen with reference to the concepts selected by Rutherford and Ahlgren in *Science for All Americans* (1990), those selected by the writers of the California Science Framework, and those selected by Judson for his book *The Search for Solutions* (1980). Additional criteria applied to selecting the concept were: (1) ease of applicability to all science areas, (2) numerous valid connections to nonscience domains of inquiry, and (3) nature of being highly workable to demonstrate content manifestations at the unit level of analysis.

The first lesson in this unit introduces the concept of change. (This lesson is based on Taba's Model of Concept Development; for more on this model, see Appendix A.) Students are asked to brainstorm examples of change, categorize their examples, identify nonexamples of the concept, and make generalizations about the concept. The following generalizations about change are incorporated into this unit of study:

- Change is everywhere.
- Change relates to time.
- Change can be natural or manmade.
- Change may be random or predictable.

Change is integrated throughout this unit's lessons, adding depth to students' understanding of matter and how the physical states of matter may change. Students examine the relationship of important ideas, abstractions, and issues through the application of the concept generalizations. For example, the "Concluding Questions and/or Actions" section of each lesson plan often includes a question that specifically addresses select change generalizations and requires students to make applications to essential science understandings. This higher level thinking enhances students' ability to "think like a scientist." Teachers should assess students' ability to apply the concept of change by seeking evidence that students:

- understand that change is everywhere,
- demonstrate the impact of time on change,
- articulate the nature of natural vs. manmade changes,
- evaluate the nature of change in selected phenomena, and
- articulate the differences between random and predictable changes.

To learn more about the implementation of concept development to the lesson plans, please read the extensive guide located in Appendix A.

## Curriculum Framework

The curriculum framework (see Table 1) developed for the Project Clarion science units is based on the Integrated Curriculum Model (ICM), which posits the relatively equal importance of teaching to high-level content, higher order processes and resultant products, and important concepts and issues. The model represents a merger between the new curriculum reform agenda and key approaches found appropriate for high-ability learners. The framework serves several important functions:

1. The curriculum framework provides scaffolding for the central concept of change, the scientific research process, and the content of the units.
2. The curriculum framework also provides representative statements of advanced, complex, and sophisticated learner outcomes. It demonstrates how a single set of outcomes for all can be translated appropriately for high-ability learners, yet remain accessible to other learners.
3. The curriculum framework provides a way for readers to get a snapshot view of the key emphases of the curriculum in direct relation to each other. The model also provides a way to traverse the elements individually through the continuum of grade levels.

Moreover the framework may be used to implement the William and Mary units and to aid in new curriculum development based on science reform recommendations.

## Standards Met

Table 2 presents detailed information on how the lessons in this unit align to the National Science Education Standards.

## Assessment

*What's the Matter?* contains performance-based assessments for students to complete at the beginning (preassessment) and end (postassessment) of the unit to assess learning within the unit itself. These assessments address concept attainment, scientific process and/or investigation, and unit content. Teachers should use the performance-based assessment results from the preassessment (pp. 27–35) to adjust instructional plans for individual learners as needed. The preassessment results also provide a baseline for determining growth after the postassessment (pp. 131–139) is administered at the completion of the unit. The postassessment

# Table 1
# Curriculum Framework for Project Clarion Science Units for Primary Grades

| Goal | Student Outcomes<br>The student will be able to: |
|---|---|
| 1. Develop selected basic concepts in 11 categories (color, letter identification, numbers/counting, sizes, comparisons, shapes, direction/position, self-/ social awareness, texture/material, quantity, time/sequence), related to understanding the world of science and mathematics. | • Provide examples, illustrations, and salient features of important science/ math concepts.<br>• Categorize and/or classify various concepts.<br>• Identify counterexamples of specific concepts.<br>• Create definitions and generalizations about individual, basic concepts. |
| 2. Develop an understanding of the concept of change as it relates to science content goals. | • Provide examples of changes everywhere.<br>• Demonstrate or identify the impact of time on change.<br>• Categorize examples of natural changes and manmade changes.<br>• Evaluate the nature of change in selected phenomena.<br>• Analyze orderly changes and random changes. |
| 3. Develop knowledge of selected content topics in science and mathematics. | • Understand that common substances are made of matter.<br>• Define matter as anything that has mass and takes up space.<br>• Identify three main states of matter: solids, liquids, and gases.<br>• Describe'objects by color, shape, texture, relative size and weight, and position.<br>• Determine physical changes in matter.<br>• Use volume to measure of the amount of space occupied by matter.<br>• Use mass to measure of the amount of matter.<br>• Conclude that materials are composed of parts that are too small to see without magnification.<br>• Analyze how physical properties remain the same when a material is reduced in size.<br>• Articulate that some liquids separate when mixed with water.<br>• Note that solids will dissolve in water, and some will dissolve more quickly in hot than cold water.<br>• Apply temperature and energy to create physical changes in matter. |
| 4. Develop interrelated science process skills. | • Make observations.<br>• Ask questions.<br>• Learn more.<br>• Design and conduct the experiment.<br>• Create meaning from the experiment.<br>• Tell others what was found. |
| 5. Develop critical thinking skills. | • Describe problematic situations or issues.<br>• Define relevant concepts.<br>• Identify different points of view in situations or issues.<br>• Describe evidence or data supporting a point of view in a situation or issue.<br>• Draw conclusions based on data (inferencing).<br>• Predict consequences. |
| 6. Develop creative thinking skills. | • Develop fluency when naming objects and ideas, based on a stimulus.<br>• Develop flexible thinking.<br>• Elaborate on ideas presented in oral or written form.<br>• Create products that replicate and extend conceptual understanding. |
| 7. Develop curiosity and interest in the world of science. | • Express reactions about discrepant events.<br>• Ask meaningful questions about science topics.<br>• Articulate ideas of interest about science.<br>• Demonstrate persistence in completing science tasks. |

# Table 2
# What's the Matter Unit: Alignment to National Science Education Standards

| Standard | Fundamental Concepts | Unit Lessons |
| --- | --- | --- |
| Content Standard A: Science as Inquiry. | Abilities necessary to do scientific inquiry:<br>• Ask a question about objects, organisms, and events in the environment.<br>• Plan and conduct a simple investigation.<br>• Employ simple equipment and tools to gather data and extend the senses.<br>• Use data to construct a reasonable explanation.<br>• Communicate investigations and explanations. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 |
| | Understanding about scientific inquiry:<br>• Scientific investigations involve asking questions and answering with what scientists already know about the world.<br>• Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).<br>• Simple instruments such as magnifiers, thermometers, and rulers provide more information than scientists obtain using only their senses.<br>• Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations.<br>• Scientists report the results of their investigations in ways that enable others to repeat the investigations.<br>• Scientists review and ask questions about the results of other scientists' work. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 |
| Content Standard B: Physical Science. | Properties of objects and materials:<br>• Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools such as rulers, balances, and thermometers.<br>• Materials can exist in different states: solids, liquids, and gases. Some common materials such as water can be changed from one state to another by heating or cooling. | 3, 6, 7, 8, 9, 10, 11, 12, 13, 15 |
| Content Standard E: Science and Technology. | Abilities of technological design:<br>• Identify a simple problem.<br>• Propose a solution.<br>• Implement proposed solutions.<br>• Evaluate a product or design.<br>• Communicate a problem, design, and solution. | 6, 10, 14 |
| | Understanding about science and technology:<br>• Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists to see, measure, and do things that they could not otherwise see, measure, and do. | 9, 10, 11 |

provides valuable information about students' mastery of the targeted objectives and National Science Education Standards.

Within both the pre- and postassessment, the following exercises are used in order to assess students' knowledge:

- The Preassessment for Change Concept (pp. 28–30) on the overarching concept, change, is administered prior to the first lesson. Students then are given assessment templates where they are asked to draw or write about certain changes. A concept assessment rubric is used to score the concept pre- and postassessments.

- In the Preassessment for Scientific Process (pp. 31–33), students are given a scientific question and are asked to design an experiment to investigate the question. A response template is given to students, and this template prompts them to identify a prediction or hypothesis, materials needed for the experiment, experiment steps, data collection, and data organization for interpretation. The rubrics are used to assess students' responses to the prompts.
- Concept maps are used to pre- and postassess students' knowledge of matter. Prior to the preassessment, students should have experience in creating concept maps to represent their knowledge (see Concept Mapping Overview in Appendix A). At the time of the actual preassessment, students are given a prompt for creating a concept map about matter. After completion, students' maps are awarded a specific number of points for hierarchical levels, propositions, cross-connections, and examples.

Teachers also should note that assessment "Look Fors" are designated in the first section of each lesson plan. These are linked to the essential science understandings, scientific processes, and change concept generalizations that are targeted in each lesson. Teachers can develop checklists for the "Look Fors" or may make informal assessment observations.

In addition to these assessment tools, teachers also will notice references to a "word wall" in the unit. The word wall is suggested for use in the classroom while teaching the unit. On this wall, teachers will post or write words (and their definitions) that go along with the lessons. Use the definitions listed on the Unit Glossary (p. 10) for the word wall. In each Materials/Resources/Equipment section of a lesson, teachers will be given words to add to the word wall that correspond to the concepts in each lesson. Then, at the end of the unit, teachers are instructed to assign words from the word wall to student groups for an activity that involves students creating word demonstrations. Teachers can assess students' understanding of each word or concept by the quality of understanding demonstrated in students' presentations.

# Lesson 6:
# The Case of the Mystery Goop

## Planning the Lesson

***Instructional Purposes:*** To understand the concept of molecules and how they act in solids, liquids, and gases; to investigate whether a mystery substance is a solid or a liquid based on the properties of matter and how molecules in matter are combined.

***Instructional Time:*** 45 minutes

***Essential Science Understandings:***
- Matter is anything that has mass and takes up space.
- There are three states of matter: solids, liquids, and gases.
- Materials are composed of parts that are too small to see without magnification.

***Scientific Investigation Skills and Processes:***
- Make observations.
- Ask questions.
- Learn more.
- Tell others what was found.
- Make predictions.

***Change Concept Generalizations:***
- Change may be random or predictable.
- Change is everywhere.
- Change may be natural or manmade.

***What to Look for in Assessment:***
- Can students generate questions and select science concepts from the scenario provided?
- Can students articulate the properties of solids and liquids to solve a problem?
- Can students discuss that matter is made up of smaller parts that react differently, depending on the state of matter?

***Materials/Resources/Equipment:***
- Large area for students to move around (move the desks or go outside)
- One eyedropper with water for the class to share
- Word wall card: molecules
- Envelope with the Mystery Goop Letter (p. 73) inside
- Chart or transparency of the Properties of Matter Concept Map (p. 74) and the Wheel of Scientific Investigation and Reasoning (p. 55)
- For each student you will need:
    - 6 tsp cornstarch
    - 1 Tbsp water
    - Bowl
    - Zipper bag

- Copies of Particles of Solids, Liquids, and Gases handout (p. 75)
- Student lab books

## Implementing the Lesson

*Part I:*

1. Open an envelope containing the Mystery Goop Letter (p. 73) Read the letter to the students yourself or ask the cafeteria manager from the school to read the letter to your class.
2. Show students the Wheel of Scientific Investigation and Reasoning (p. 55). Ask students to determine what questions they may have about the mystery substance. Write them on their paper or the back of the handout. Brainstorm a list of questions as a group based on what the students wrote.
3. Ask the students what the cafeteria manager needs to find out. (Is the substance a liquid or solid?)
4. Ask students to complete their hypothesis about the two questions at hand.
5. Ask students how they might test their hypothesis. After several ideas, help lead students toward recreating the substance to observe with their senses (except taste) how the substance acts.
6. Ask students to consider what ingredients were included in the manager's discovery (cornstarch and water that looked like mayonnaise). Give each student a bowl and some cornstarch and water. Ask them to add just a little bit of water to the cornstarch until it begins to look like mayonnaise. Once they have a good consistency, tell the students to observe the cornstarch and water by picking it up, squeezing it, scooping it, setting it back in the bowl, and so forth. (Usually 6 tsp. of cornstarch and 1 Tbsp. of water will be sufficient to create a good consistency. If the mixture gets too stiff, add a few drops of water with an eyedropper.)
7. After students have found the right consistency, the cornstarch mixture should liquefy and ooze through the student's fingers but solidify when squeezed. Once students have had time to discover how the mixture reacts ask the following questions:
   a. What is the mixture?
   b. What properties does the mixture have?
   c. Does it act more like a solid, liquid, or gas?
   d. How might we classify this mixture? Allow time for students to defend whether or not they believe the mixture is a solid or liquid.
   e. What is happening to the mixture when we squeeze it?
   f. What are we going to tell the cook?

8. Tell students to put their mixture in a baggie and clean up their area. Tell them you will help them figure out what is happening to the mixture. You might have some ideas that will help the cook out that have to do with things we cannot see.

*Part II:*

1. To review the three main states of matter with the students, complete the Properties of Matter Concept Map (p. 74); see Figure 4 below for examples. Use the following questions as a guide:
   a. What does all matter have?
   b. What does matter take up?
   c. What are the properties you observed about solids? Liquids? Gases?

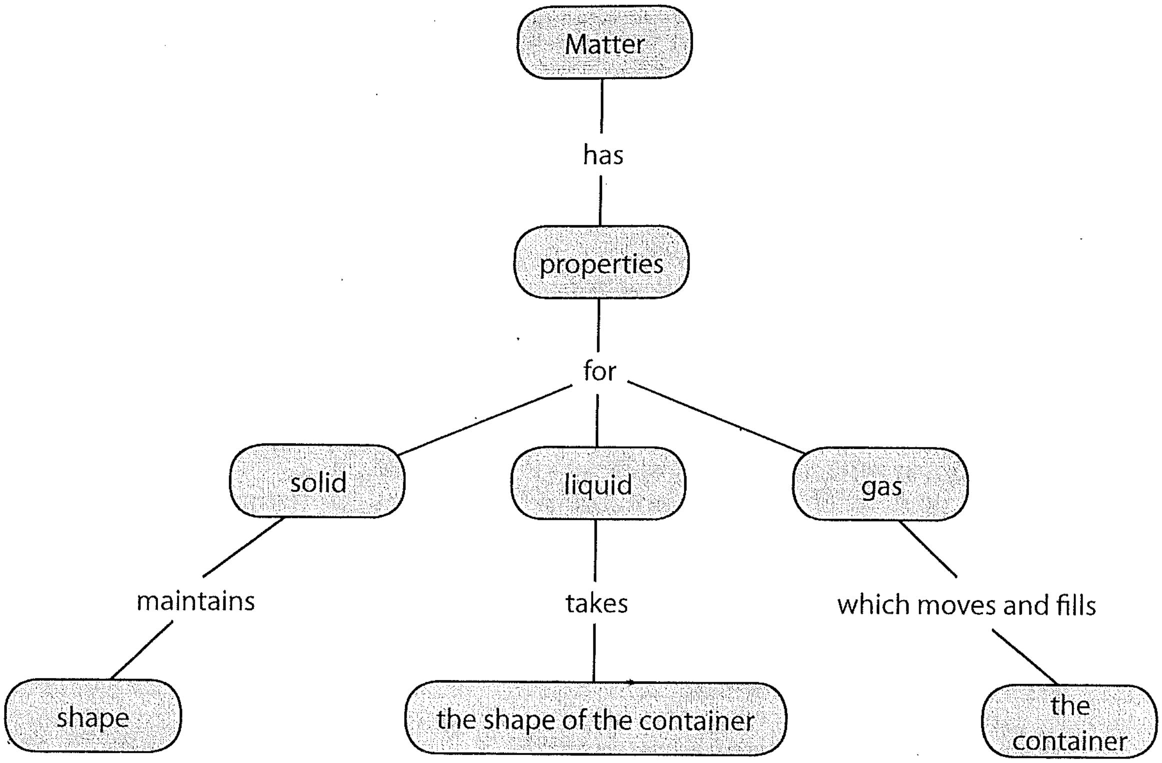



**Figure 4.** Example of concept map for the three states of matter.

2. Remind students about the experiment with the paper towel and the glass. Even though we can't see air, we know it is there. Explain to students that while solid and liquid matter has many properties that we can observe with our five senses, there are also properties of matter that we cannot see. Write the word *molecules* and the following definition on the board: "a small particle, a tiny bit; the smallest particle of a substance that retains the chemical and physical properties of the substance."
3. Explain to students that molecules behave differently depending on whether they are part of a solid, a liquid, or a gas. Because we cannot see molecules, except with the use of a very strong microscope, we are going to use our bodies to demonstrate how molecules move within each state of matter.
   a. *Solid:* The particles that make up a solid are packed closely together and attracted to each other very strongly; they do not move around much. Choose 12 students to be the "molecules." Have three students stand side-by-side. Line up the remaining students in columns behind these students. The group of students should form a square. Have each student rest his or her left arm on the shoulder of the person in front of him or her and rest his or her right arm on the shoulder of the person to his or her right. In this formation, students represent the molecules of a solid, with their arms signifying the strong attractive forces that hold the molecules of a solid together. Solids are solid because their molecules are compact.
   b. *Liquid:* The particles that make up a liquid are attracted to each other a little bit less and move around more. Have a different group of students (about 10–12) stand together in a group. Tell them they can move around, pass each other, and changes places as long as they are always within touching distance of another student. This formation is like a liquid. Molecules are attracted to each other and remain fairly close, but they can

slide past each other. Liquids take the shape of their containers because their molecules are loosely aligned.

   c. *Gas:* The particles that make up gas have the least attraction to each other and move around the most. Have another group of students (10–12) begin by standing in a group. Tell them they can go wherever they like and do not have to be within touching distance of another student. This is like the behavior of gas molecules.

4. Distribute Particles of Solids, Liquids, and Gases handout (p. 75). Have students complete the handout independently. Discuss individual answers with the whole class.
5. Once students have successfully completed the activity, ask them if anyone has ideas about what the cook's substance is and why it acts the way it does. Students should be able to explain that the new substance acted like both a liquid and a solid. When the substance was squeezed together quickly, the molecules in the goop were compacted and made it appear to be solid. Because cornstarch and water do not mix well, when you let go of the mixture it acts more like a thick liquid, meaning that the molecules relax and are not as compact as a solid. This is called a *suspension*. This means that the cornstarch and water do not really mix completely. Instead the cornstarch molecules glob together and are suspended in the water. Milk is another example of a suspension. Tell students to go home and add a few drops of milk to water and observe what happens.
6. Engage students in a discussion using the following questions as a guide.
   a. How did you use the Wheel of Scientific Investigation and Reasoning to figure out what the new substance was? Review the wheel components if necessary.
   b. How do you think the cook should dispose of the goop?
   c. How does the goop change if a lot of water is added?
   d. How does the goop change if more cornstarch is added?

7. Ask students if they can think of additional questions they might want to investigate for the Matter Conference. They should write their ideas in the marked section of the lab book. *Note:* Emphasize to students that even though the goop may act more like a liquid because it takes the shape of its container, they should never put anything down the sink except water unless they have permission. Dispose of the goop in the trashcan.
8. Concluding Questions/Actions:
   a. Ask students to help you make a list of science words (concepts) that were used in this lesson. Tell students to talk with a partner about these words and what each of the words means. Then ask for volunteers to use one of the words in a sentence that talks about something they learned in the lesson. Create a chart of sentences.
   b. Ask students to date and write a new entry in their student lab books: Write a letter or draw a diagram to show the cafeteria manager about molecules and the properties of solids, liquids, and gases. Share with a partner and compare your answers.

## Extending the Lesson

### *What to Do at Home*

- Show your mystery goop to your family. Explain about molecules of solids, liquids, gases, and suspensions. Lead your family through the activity we did in class to show them about solid, liquid, and gas molecules.
- Add a few drops of milk to a cup of water and watch what happens. Milk and water do not mix. The milk will suspend in the water. Explain why that happens. Ask your family if you can test other liquids to see if they suspend or mix. Make a table to record your results. Share them with the class.

# Mystery Goop Letter

Dear Students,

I heard you might be hosting a Matter Conference and I have something that might be of interest to you. Last night in the cafeteria, I had an awful mess in the sink. Our cafeteria has a leaky faucet. I forgot about the leaky faucet and left a box of cornstarch in the sink. By morning, I had mystery goop overflowing in the sink. A new substance was made and I can't figure out what it is. It looked a lot like mayonnaise.

I'm not sure whether this material is a solid or a liquid. I heard about your Matter Conference you are planning for and thought you might know something about this, too.

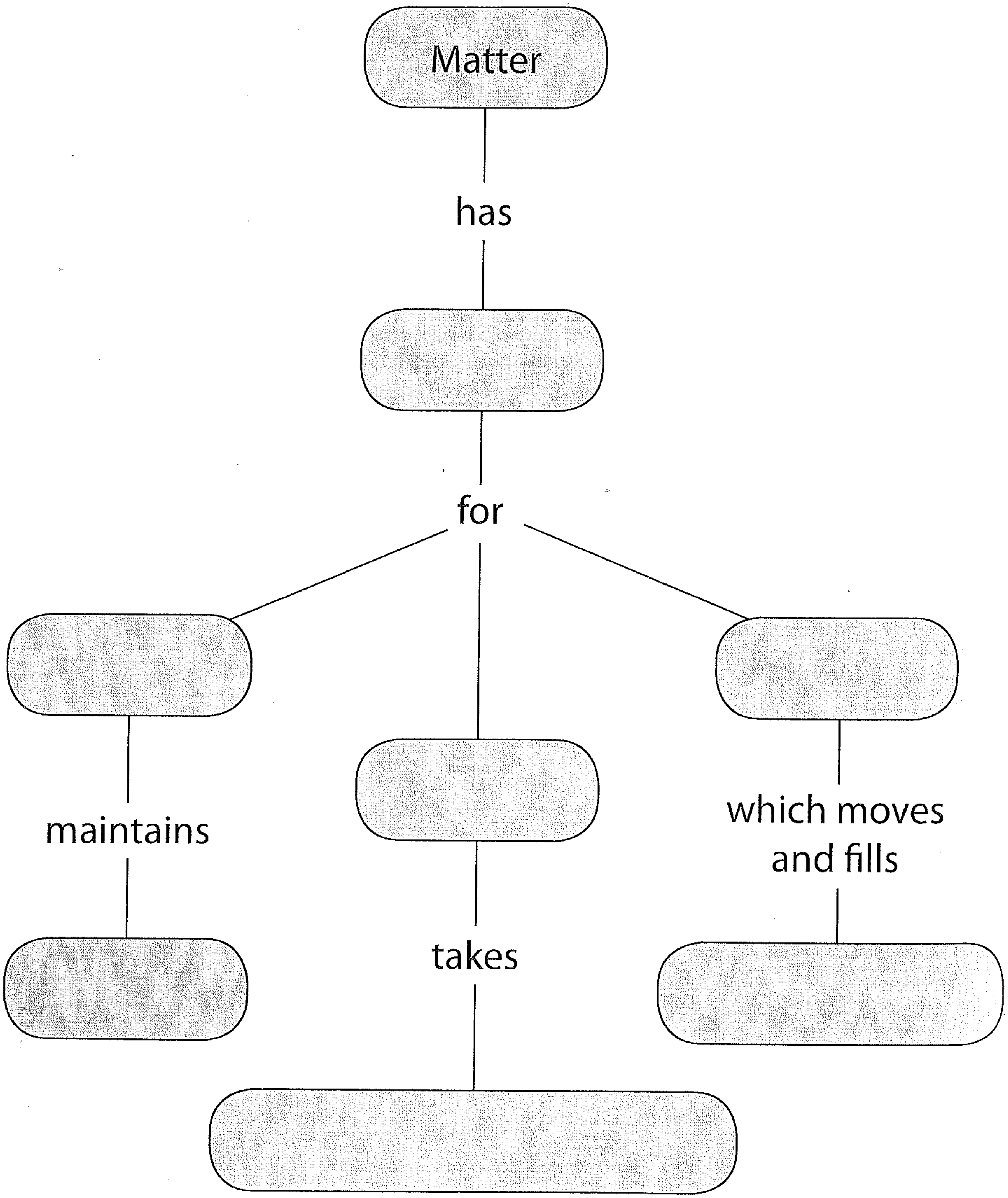
Please help. I need an explanation of what this substance is and why it acts like it does!

Sincerely,

Cafeteria Manager

Name:______________________________ Date:______________

# Properties of Matter Concept Map

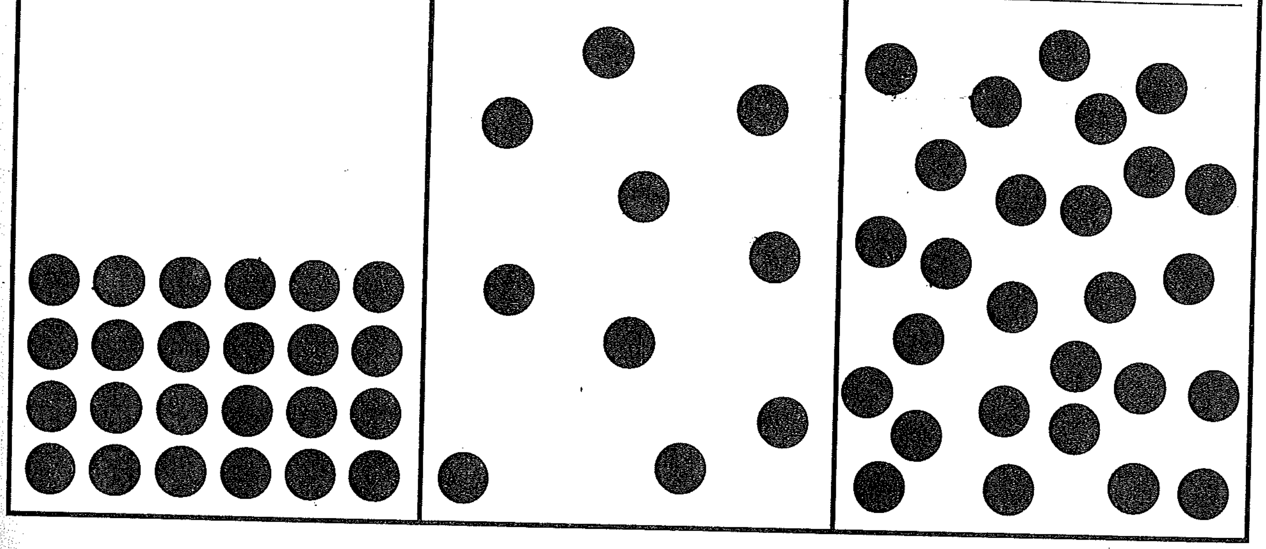


Name:______________________________ Date:_______________

# Particles of a Solids, Liquids, and Gases

**Directions:** Label each diagram as solid, liquid, or gas. Then answer the two questions below.

| **Particles in a** ____________ | **Particles in a** ____________ | **Particles in a** ____________ |
|---|---|---|



Compare the particles in a solid to the particles in a liquid. How are they different?

____________________________________________________

____________________________________________________

____________________________________________________

____________________________________________________

Compare the particles in a liquid to the particles in a gas. How are they different?

____________________________________________________

____________________________________________________

____________________________________________________

____________________________________________________