UNIT INTRODUCTION

Discuss with your students some things that are not matter. Note: Define matter as any solid, liquid or gas. Ask them to name some things that are not matter. These may include the vacuum of outer space, forms of energy such as light and heat, or abstract concepts such as temperature, force, and love.

INTRODUCTION TO LESSON CLUSTER 1

STATES OF WATER

A. Lesson Cluster Goals and Lesson Objectives

Goals

Students should be able to describe the three states of water in terms of the arrangement and movement of water molecules.

Lesson Objectives

1.1. Describe ice (solid water) and liquid water as two different states of the same substance.

1.2. Describe ice (solid water), liquid water, and water vapor as three different states of the same substance.

1.3. Describe liquid water as composed of invisible water molecules.

1.4. Describe the differences among the three states of water in terms of the arrangement and movement of water molecules.

Describe the unique properties of water and how these properties affect our lives.

B. Key Elements of a Good Description

1. At the visible or macroscopic level, students should be able to state that ice, liquid water, and water vapor are the same substance. Liquid water changes into ice or water vapor by heating or cooling. During the changes of states, liquid water does not disappear or change weight.

2. Students should recognize that there is invisible water vapor in the air.

3. At the invisible molecular level, students should explain the observable properties of ice, liquid water, and water vapor in terms of the arrangement and motion of water molecules. Key points include the following:

a. Ice, liquid water, and water vapor are all made of water molecules, H_2O.

b. Water molecules are too small to be seen, even with a microscope, and they are always in motion.

c. Ice, liquid water, and water vapor differ in the arrangement and motion of water molecules:

- Ice: Water molecules are locked in rigid pattern, and vibrate in their places.

- Liquid water: Water molecules slide and bump past each other.

- Water vapor: Water molecules move freely with much more space between them than in the liquid of solid state.

C. Conceptual Learning

This lesson cluster introduces the unit by focusing on water, a substance that is familiar to students in its solid (ice), and liquid (water) states. This substance is used to introduce many key ideas of the unit, ideas that will be applied repeatedly throughout the unit. Some of the ideas that may cause difficulty for your students are discussed below.

Lessons 1 and 2:

At the observable or macroscopic level, students must recognize the essential sameness of water in all three states of water. First, although most students understand that ice and liquid water are the same substance, a variety of subtle misconceptions are common:

a. Some students believe that when ice melts into water, it loses weight, because ice is solid or hard.

b. Some believe that when water evaporates, it loses it weight, or that when water evaporates, it disappears or becomes weightless.

Second, many students have difficulty with the idea of water vapor. The cause of the difficulty is that water vapor is invisible, whereas ice and liquid water are observable. Many students have the following common misconceptions:

a. Water does not change into gas, or water vapor.

b. "Foggy steam" from boiling water is the gaseous state of water. It is not; it is really tiny drops of liquid water.

c. There is no water vapor in the air. Students who believe this have difficulty understanding condensation in Lesson Cluster 9.

d. The bubbles in boiling water are air.

D. Concepts that are difficult for students to understand.

At the invisible or molecular level, you will probably find that many of your students have not heard of the word "molecules." Even if some students have heard of it, their understanding is

likely to be substantially different from the ideas conveyed in this unit. Furthermore, although many students might have heard of the term atoms, their understanding may not be scientific. Their acquaintance with the term atoms may even interfere with the new molecules.

1. **Size of molecules**
   The size of a molecule is one characteristic that is difficult for students to understand because it lies outside the realm of their normal experience. Although students think of molecules as small, it is hard to convey just how small they are. Many students think of molecules as similar in size to other tiny objects that they are familiar with, such as specks of dust, bacteria, or cells. Even if they say that molecules are smaller than these objects, they may still think that they can see molecules with a microscope. In reality, a typical human cell contains perhaps 100 trillion molecules; a dust speck, even more. Thus, molecules are too small to be seen.

2. **Molecules are in constant motion**
   Students also have difficulty in understanding that molecules are constantly moving. Molecules are always moving, even in substances such as ice where no motion of the substance is visible. Many students think that molecules are moving in liquid water because liquid water is flowing, but molecules are not moving in ice because ice is not moving. The constant motion of molecules is difficult for students to believe, both because it seems to contradict the evidence of their senses and because they have never encountered objects that, like molecules, are so tiny that they are unaffected by friction and thus never come to a stop.

3. **The behavior of molecules creates properties of a substance**
   Students are confused between observable properties of a substance and properties of the molecules themselves. Many students may believe, for instance, that molecules of water become hard and cold when the water freezes, rather than simply becoming locked into a rigid arrangement and motion in their places. Some students may even think that when water changes into ice water, water molecules change into ice molecules.

4. **Molecules make up substances**
   Many students believe that there are molecules in substances rather than the substances are made of molecules. For example, they think that water <u>contains</u> molecules (like blueberries in a muffin) rather than <u>consisting</u> of molecules and nothing else (like grains of rice). Students may think there is "air" or "water" between water molecules. Thus, it needs to be strongly emphasized that water is made of only molecules and there is nothing between water molecules.

E. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Conservation of matter	Matter is conserved in all physical changes.	Matter not always conserved, especially in changes involving gases (e.g., water disappears when it is heated).
Water vapor in air	Air contains invisible water vapor.	Water in air is visible (e.g., fog, "steam"). There is no gaseous state of water.
Molecular constitution of matter	All matter is made of molecules.	Molecules are in substances (e.g., water has molecules in it, with water between the molecules).
Size of molecules	Molecules are too small to see, even with a microscope.	Molecules may be comparable in size to cells, dust specks, etc. Molecules can be seen with a microscope.
Constant motion	All molecules are constantly moving.	Molecules may sometimes be still, especially in solids.
Visibility of molecular motion	Molecular motion continues independently of observable movement.	Molecules simply share in observable movements of substances (e.g., molecules do not move in ice because ice is frozen).
Molecular explanation of states of matter	States of matter are due to different arrangements and motions of molecules: -solid: vibrate in rigid array. -liquid: random motion within limits. -gas: random motion, no limits.	States of matter described only in terms of observable properties of the state attributed to individual molecules (e.g., water molecules are hard in ice.)

LESSON 1.1

SOLID WATER AND LIQUID WATER

PURPOSE:

To help students describe ice and liquid water as two different states of the same substance.

ADVANCE PREPARATION:

For each group of 2-3 students you will need ice cubes and a ziplock plastic bag which will provide a water tight seal, and a balance to weigh the ice cube-plastic bag system.

MATERIALS LIST:

For each group of students:	For the class:
one ice cube	one balance
one ziplock plastic bag	

TEACHING SUGGESTIONS:

Have the students read the first two paragraphs of the student text. Elicit as many student responses as possible to the question "How do you know that ice is really solid water?" Discuss the student responses until students understand the problem for the activity.

When you begin to talk about gases, be alert to any student confusion between "gas" and gasoline. Although gasoline is a liquid some people shorten the word to "gas."

LESSON 1.2

SOLID, LIQUID, AND GAS

PURPOSE:

To help students describe liquid water and water vapor as two states of the same substance. To have students infer that ice, liquid water, and water vapor are three states of the same substance.

ADVANCE PREPARATION:

In order to demonstrate the distillation of water, you should collect the materials and assemble the apparatus before class. A drawing of the apparatus on page 3 of the Science Book will help you visualize the setup. You should start heating the water about 10 minutes before class so it is operating during class without any drops of water in the connecting tube. By having the apparatus operating before the students observe it carefully, you can usually prevent some students thinking that drops of liquid water that are in the tube are water vapor.

MATERIALS LIST:

hot plate	small Erlenmeyer flask with one hole stopper
test tube	glass tubing including two right angles
beaker	

TEACHING SUGGESTIONS:

Before you do this activity, you should be aware of how we use "steam" in this unit. Technically, steam refers to hot water vapor, so both steam and water vapor are invisible. However, this is contrary to the way steam is used in everyday conversation. To most people, steam is the "fog" or "white cloud" above boiling kettles or coming off a hot shower. This usage is so common that it is confusing to confront grade 6 students with the scientific definition. Therefore, for the purposes of this unit, we use the technical definition of water vapor (that it is an invisible gas) and the nontechnical, or common, usage of steam (that it is a "white cloud" or "fog").

1. Have the students read the first portion of the student text and discuss it completely.

2. The students should answer question #1 in the Activity Book (Question Set 1.2) before they observe the distillation of water closely.

3. Do the demonstration, have the students complete the Question Set, and discuss their responses completely.

4. Continue with the Science Book. Stress that water vapor is always invisible and that there is always water vapor in the air. Also emphasize that ice, liquid water, and water vapor are three states of the same substance.

LESSON 1.3

MOLECULES, THE SMALLEST PIECES OF WATER

PURPOSE:

To introduce the molecular theory of matter and to help students describe liquid water as composed of invisible molecules that are constantly moving.

MATERIALS LIST:

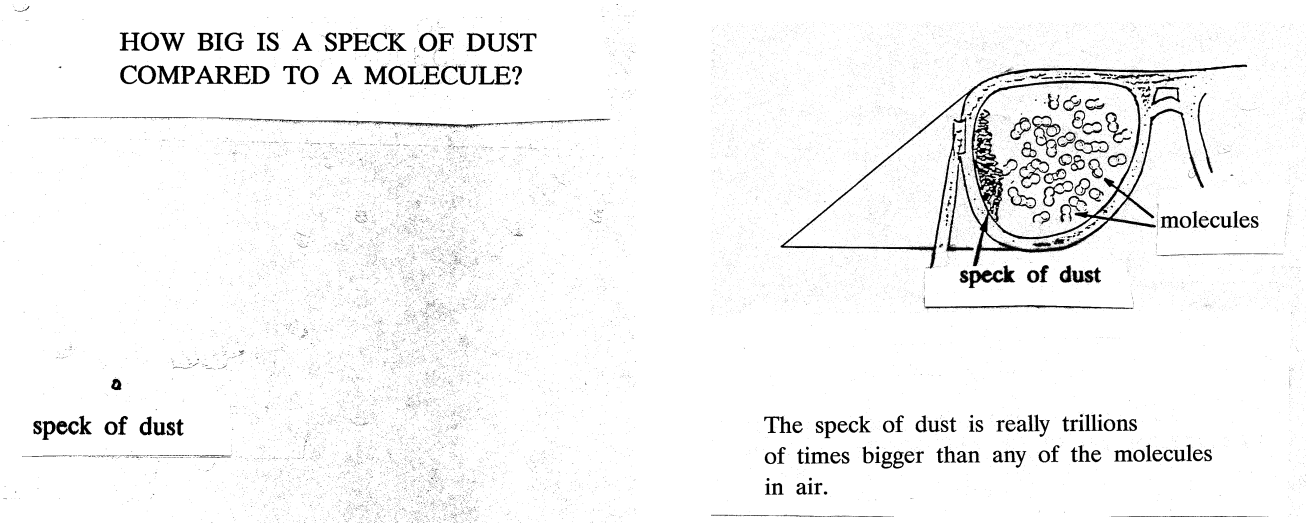
Transparency 1: How big is a speck of dust compared to a molecule?

TEACHING SUGGESTIONS:

You may want to re-read the section, Students' Conceptual Learning, found in the Introduction at the beginning of Lesson Cluster 1. In re-reading this section, please note that most students have difficulty believing that water is made of molecules and nothing else. Some students come to think that there are molecules in the water rather than water consisting of molecules and only molecules. You should stress, therefore, that water is made of only water molecules and nothing else. Students also have difficulty believing that molecules are constantly moving, especially in a solid like ice. These two concepts are among the most important concepts in the entire unit as well as in this lesson.

The first paragraph gives you the opportunity to review the major concepts taught in lessons 1.1 and 1.2. You may also want to stress that when ice changes to liquid water, the water has exactly the same number of molecules as did the ice. Thus, there could not be a change in weight. The same is true for liquid water changing into water vapor.

Molecules of water are actually shaped somewhat like the way we have drawn them (see Science Book page 6). This "Mickey Mouse" shape is easy for students to remember. Atoms of hydrogen and oxygen are not solid balls, as the drawing suggest; each atom actually consists of a "cloud" of electrons surrounding a nucleus made of protons and neutrons. But water molecules and other molecules often do act like small hard particles. This is a good place to use Transparency 1:



TRANSPARENCY 1: HOW BIG IS A SPECK OF DUST COMPARED TO A MOLECULE?

BOTTOM LAYER:

Many students believe that molecules are about the same size as or perhaps a little smaller than a speck of dust, a cell, or a germ. Encourage students to express their answers to the question.

OVERLAY:

Many students may have difficulty with understanding the relative size of molecules. Contrast students' incorrect ideas with the scientific notion that the speck of dust is really trillions of times bigger than the molecules of air. Reference to the comparison of a cell with water molecules (illustration: Science Book page 7) may help. [A trillion is equal to 1,000,000,000,000.]

All students have difficulty comprehending how incredibly small molecules are. Although it is not necessary for students to know exactly how small molecules are, they should definitely get the impression that they are very, very small, are constantly moving and never stop moving even in solids such as ice.

LESSON 1.4

MOLECULES AND THE THREE STATES OF WATER

PURPOSE:

To help students describe the differences among the three states of matter in terms of the arrangement and movement of water molecules.

TEACHING SUGGESTIONS:

In using this lesson with students, stress that the difference in properties among ice, liquid water, and water vapor is due to the arrangement and movement of the molecules and not due to any change in the molecules themselves.

Also, stress that molecules are constantly moving and never stop, even in a solid.

Stress that the differences among the three states of matter is the result of the **arrangement** and **movement** of the molecules and not due to changes in the molecules themselves.

SUPPLEMENTARY READING

THE MIRACLE OF WATER

PURPOSE:

To help students describe the uncommon properties of water and how these properties affect their lives.

TEACHING SUGGESTIONS:

We use water frequently in our science activities because it is available, familiar to students and inexpensive. Students need to know, however, that many properties of water are not typical of most substances.

You should use this lesson to emphasize these exceptional properties of water. The exceptional properties include:

1. Most living things contain more water than any other substance.

2. Water dissolves a greater number of other substances than any other substance.

3. Water has a great capacity to retain heat.

4. Most liquids contract when they freeze. Water expands between 4^{o} C and 0^{o} C.

5. Water changes from one state to another within a narrow temperature range. There is always water as a gas (water vapor) in the air, liquid water in the oceans, and solid water (ice) at the earth's poles.

Discuss these properties to help students describe the uncommon properties of water.

MATERIALS LIST

CLUSTER 1, LESSONS 1.1-1.4

Lesson 1.1:

For each group of students: one ice cube and one ziplock plastic bag. For the class: one balance (optional).

Lesson 1.2:

one hot plate
one small Erlenmeyer flask with a one hole stopper
glass tubing including two right angles
one test tube
one beaker

Lesson 1.3:

Transparency 1

Lesson 1.4:

None