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BASIS Lesson Plan

Lesson Name: States of Matter

Grade Level: 5

Presenter(s): The Long Group

Standards Connection(s):

California Science Standards: Grade 5 Physical Sciences
Next Generation Science Standards: Grade 5 Physical Sciences

**Note to teachers: Detailed standards connections can be found at the end of this lesson plan.*

Teaser/Overview

Solids, liquids and gases make up the world around us. Each of these forms of matter has unique, important properties that shape our lives. Your students will learn about these properties through the four stations in this hands-on, demonstration-focus lesson.

Lesson Objectives

Solids Station: Students will make hypotheses about the mass and density of three solid objects. After learning more about these two properties of matter, they will brainstorm an experiment to test their hypotheses.

- Students will practice making and testing hypotheses.
- Students will learn about the concept of density and how it can be measured.
- Students will also learn to distinguish between the concepts of mass (weight) and density.

Liquids Station: Students will layer liquids of different densities on top of each other. They will use these density columns to discuss the densities of liquids and how they can vary (e.g. dissolving a lot of salt in water will increase its density because it will have more mass in the same volume). They will also discuss miscibility, whether or not two liquids mix. Finally, the volunteer will pull solid nylon from the interface of two non-miscible liquids.

- Students will learn about the densities of liquids and how they can vary with dissolved solutes.
- Students will learn about the concept of miscibility and will see an example of a chemical reaction occurring between two immiscible liquids.

Gases Station: The volunteer will fill a fish tank with dry ice and allow the tank to fill with CO_2. Students will discuss how the volume of the gas is determined by discussing balloons. Then, students will hypothesize about whether carbon dioxide is more or less dense than air and will test their theory by blowing bubbles into the fish tank.

- Students will learn how the volume of gases can vary with pressure, while those of solids and liquids are fixed. They will also discuss the idea of pressure.
- Students will also learn about the density of gases and how this causes them to float or sink.
- Students will learn to design an experiment to test something that they cannot see with their eyes or feel (the density of a gas).

Other States of Matter Station: Students will examine and describe the properties of a corn-starch and water solution. This material that is both solid and liquid will be used to start a discussion about materials that fall outside the classification of solids, liquids, and gases. It will also be used to discuss viscosity, an important property of liquids. Students will brainstorm other materials that fall in this category (such as silly putty, ketchup, etc.) and will come up with ideas of how they could be used.

- Students will learn about states of matter that fall outside the traditional classification of solids, liquids, and gases
- Students will be introduced to the idea of non-Newtonian fluids and how forces can affect the behavior of matter (particularly viscosity).
- Students will think about how the properties of a material could be applied to a problem in society (e.g. corn starch and water could be used to fill a pothole, since it could mold to the right shape and then be solid when a car drove over it)

Vocabulary Words

- **Density**: mass per unit volume
- **Miscible**: a property describing whether or not two liquids mix
- **Viscosity**: a property of a liquid that describes the thickness of its consistency (its gooiness)
- **Pressure:** (with respect to gases) a property of gases that describes how hard gases push outward against the containers that hold them and also how hard external forces press against the gas, preventing it from expanding

Materials

Scientist Volunteers will bring:

Solids Station:
Three object of various densities and equal masses (e.g. metal, Styrofoam and wood)
A large, clear container (to fill with water and test the objects' densities)

Liquids Station:
Oil, water and a saturated saltwater solution (dyed three different colors with food dye)
Several clear-sided cylinders (cups or otherwise)
0.5M hexamethylenediamine solution
0.2M sebacoyl chloride solution in hexanes
Glass beaker

Gases Station:
Fish tank
Dry ice
Bubble solution
Balloons

Other States of Matter Station:
Saturated cornstarch and water solution
Plastic sheet to cover the ground

Materials teachers should provide:
n/a

Classroom Set-Up

The lesson will consist of four stations, so it would be ideal if the desks could be moved into four distinct areas (or those areas could be designated in some other way).

Classroom Visit

1. Introduction (5 minutes)

Role Model Introduction:
Being a role model for students is an important part of being a BASIS volunteer. Begin your lesson by introducing yourselves! Every team member should take a moment to explain who they are and what they study/do as a scientist. A bonus will be to tell your "story," as if giving an elevator pitch to 8-year-olds: Why did you become a scientist? What made you interested in your topic? Why should students relate to you, or be interested in you? Feel free to draft a script of what you will say, here. And remember, you can also weave your story throughout your lesson through examples from your own life, and/or return to it with Q&A at the end.

Topic Introduction:
Ask the students to define matter. Write their suggestions on the board and combine them until you get a good working definition (should me along the lines of "anything that has mass and takes up space"). Write this definition at the top of the board.

Explain to the students that matter is often classified according to its state, whether it is a solid, a liquid or a gas. Write these three terms underneath the definition and have the students list a few properties of each category. Write these properties underneath the term. Try to focus them towards properties that are unique to each category.

Explain to the students that the lesson will consist of four stations, each focusing on one of these different states of matter and some of its unique properties. Based on the properties that they listed, try to contextualize why understanding the properties of each unique state of matter is important (e.g. "understanding how solids react to forces is important for designing buildings or bridges," "understanding how gases expand or contract is important to designing an engine," etc.). Divide the class into four groups and then assign each group to a station.

2. Solids Station (10 minutes)

To begin, the volunteer should pass around the three objects and ask the students to weigh them in their hands. Start a discussion by asking, "Which of these objects is heaviest? Which is lightest?"

After the students have offered ideas, continue the discussion by asking, "What do you mean by heavy? What physical property are you measuring?" If necessary, introduce the idea of mass yourself (e.g. "When we discuss weight, we're usually talking about the amount of matter that makes up an object. That's a property we call mass.").

Once the idea of mass is introduced, tell the students, “Would you be surprised if I told you that all of these objects are actually the exact same mass? If you put them on a scale, they would all weigh the same amount.” Ask them, “Does anyone know what property you’re actually measuring when you feel the difference in the objects?”

Try to steer the discussion towards density by pointing out the difference in volumes of the objects, if necessary. Introduce the idea of density yourself if necessary (e.g. “All of these objects have the same mass, but they have different volumes. Spreading the same mass over a larger volume gives the object a lower density, which makes it feel lighter. Your body is actually much more sensitive to differences in density than mass, that’s why the piece of Styrofoam feels lighter than the piece of metal, even though they weigh the same.”).

Next, ask the students to brainstorm an experiment that they could use to prove that the objects have different densities and to rank their density. Let them propose several ideas before steering the discussion towards putting the objects in water to see if they float or sink.

Have the students put each of the objects in the tub of water. Discuss what happens with each object (e.g. The piece of metal sinks because it is more dense than water. The piece of Styrofoam floats because it is less dense). Ask the students, “Since both Styrofoam and wood float, our experiment doesn’t show which one is more dense. How could we design an experiment to figure that out?” One possible solution would be to find a less dense fluid (such as oil), though students may come up with others.

Start a discussion about the differences between mass and density, if there is time. Ask the students, “How would the mass and density of the piece of Styrofoam change if I broke it in half?” Steer them to the correct answer with questions if necessary (e.g. “Would the Styrofoam still float if I broke it in half? Yes, because it has half the volume and half the mass, so it has the exact same density). Emphasize that density is an intrinsic property of a material, something scientists sometimes call an intensive property, while mass varies with the amount that you have, something termed an extensive property.

The main emphasis of this station is the difference between mass and density. Try to emphasize this throughout and summarize at the end by asking students to define each term and explain the difference. Mass is the amount of matter that makes up something. Density is the amount of mass per unit volume. Mass can change depending on how much of something you have, whereas density is an innate property of a material that will stay the same no matter how much of the material you have.

3. Liquids Station (10 minutes)

Warning: The solutions for the nylon-pulling demonstration are corrosive and flammable. The volunteer should keep them away from the students and should warn them not to touch them. The volunteer should wear nitrile or rubber gloves and eye protection when performing the demonstration.

Begin the demonstration by asking the students, “Do all liquids mix?” Have them discuss and offer examples.

Take a clear cup (or other cylindrical container) and pour in an equal amount of oil and tap water. Tell the students, “Miscibility is a property of liquids that determines whether or not they will mix with other types of liquids. Because it won’t mix, we say that water is immiscible with oil.”

Ask the students, “Why does the oil layer float on top of the water?” Start a discussion about the density of liquids.

Ask the students, “Do you think this salt water solution will be more dense or less dense than normal tap water?” Have them offer explanations for their hypotheses and to propose experiments to test them. If the correct answer has not come up, explain “Salt water is more dense than normal water because it has more mass in the same volume. Dissolving salt doesn’t increase the volume of the water, but it does add mass to it.”

Have the students layer the three liquids to make a density column, pouring the salt water into the cup first, then adding the tap water and finally the oil. Warn them, “Water and salt water are miscible, so they will mix if you do not pour the water on top of the salt water very gently.”

After the density columns are finished, direct the student’s attention to the nylon-pulling demonstration. Explain to the students that a chemical reaction is occurring where the two immiscible solutions meet, forming a solid. Pull out the solid to show them using tweezers (pull gently, as it breaks easily). Explain that nylon is a polymer and ask them to brainstorm any other polymers that they might know (most plastics and synthetics).

The main emphasis of this station is the miscibility and density of liquids. Make sure to emphasize that miscibility dictates whether or not two liquids can mix and that it is an innate property arising from the particular type of liquid. Also make sure that students understand that the density of liquids can be increased by dissolving materials in them.

4. Gases Station (10 minutes)

Warning: Dry ice is extremely cold and should not come into contact with bare skin. Warn the students not to touch it before beginning the station.

The volunteer should fill the fish tank with dry ice before the students have arrived at the station (preferably five to ten minutes before to give time for CO_2 to fill the tank).

Ask the students, “Is the volume of a gas constant or does it change? Is it like a solid or a liquid, or is it different?” Steer the discussion towards the fact that the volume of a gas is variable, while that of a solid or a liquid is much harder to change.

Further the discussion by asking, “What controls the volume of a gas?” Inflate a balloon and use it to steer the discussion. “Why does the balloon stay this size? Why doesn’t it grow more or less?” Prompt them if necessary, “Have you ever seen a helium balloon float into the sky? What happens to it when it gets really far up?”

If necessary introduce the idea of pressure yourself. (e.g. “The gas inside that balloon expands until it is stopped by atmospheric pressure, the weight of the earth’s atmosphere pushing down on us. When a balloon goes higher into the atmosphere, the pressure goes down and so the gas inside it can grow more. This happens until the balloon stretches too much and it pops.”) End the discussion by reinforcing, “The volume of a gas can change and is controlled by the external pressure pushing back against the gas molecules as they try to take up more space.”

Turn the students attention to the fish tank. The volunteer should start by explaining, “Dry ice is a solid form of carbon dioxide. At room temperature, it goes straight from a solid to a gas. Does anyone know what that’s called?” If necessary, introduce the idea of sublimation (e.g. “Sublimation is just like melting, freezing or evaporating. It’s a way that matter moves between different states, in this case from a solid to a gas.”)

Ask the students, “Do you think carbon dioxide is more or less dense than air?” After they come up with a hypothesis, ask them to come up with an experiment that would show this using the bubble solution and the fish tank. If necessary, introduce the experiment yourself (e.g. “We can blow bubbles of air and see if they float or sink on the carbon dioxide in the fish tank. If they sink, air is more dense, and if they float, it’s less dense.”)

Have the students blow bubbles into the fish tank to test their hypothesis (Note: It’s best for the students to blow the bubbles out and over the tank, rather than down into it. They tend to float better and this will prevent the carbon dioxide from being displaced by students blowing into the tank).

If there is time, ask the students, “Is there any way that we could make the air more dense than carbon dioxide?” Try to steer the discussion towards changing the volume. If necessary, introduce the idea of pressure changing the density yourself (e.g. “Since we can change the volume of a gas, we can change its density. If we lower the volume, we will have more mass in a smaller space and so a higher density. If we somehow put the air under a high pressure to lower its volume, we could make it more dense than CO_2).

The main emphasis of this station is that the volume of gases can change with the external pressure. Make sure to emphasize the fact that the volume of gases is variable and that it is controlled by the forces pushing back against the gas molecules as they try to expand to take up more space.

5. Other States of Matter Station (10 minutes)

The volunteer should prepare for this station by combining cornstarch and water until a thick solution forms. It should pour like a viscous liquid, put should feel solid when you press on it firmly. You can add some food color to make it an interesting color.

Prepare the station by spreading a plastic sheet on the ground. Alternatively, put the cornstarch solution in sandwich bags to keep it from getting everywhere (it's more fun for the students to be able to hold it in their hands, though, so the plastic sheet method is better).

Introduce the station by telling the students, "We usually classify a substance as a solid, a liquid or a gas, but some things fall outside of these categories."

Have the students make their own cornstarch solution in a cup or bag. Take a couple spoonful's of cornstarch and then slowly add water, while mixing, until all of the powder is consumed and a thick mixture has formed. If the solution is too thin, add a bit more cornstarch. Ask the students to describe the properties of the solution to you. Ask them to classify these properties as properties of solids, liquids or gases. (e.g. "You can pour the mixture like a liquid," "The mixture is hard when you press it, like a solid," etc.).

Ask the students, "Is the corn starch mixture thicker or thinner than normal water?" Use this to introduce the idea of viscosity (e.g. "Viscosity is a property that describes the thickness or goopiness of a liquid.").

Ask the students, "How does the viscosity of the corn starch-water mixture change when you press it?" They should notice that the viscosity increases, making it seem more like a solid than a liquid. Introduce the category of non-Newtonian fluids (do not need to mention this term), "There are some materials that change viscosity when you apply pressure. Can you think of any others?" Have them brainstorm ideas (common ones include ketchup, which decreases viscosity when you squeeze it, and silly putty, which increases viscosity when you apply a force).

To end the station, have the students brainstorm uses for these materials (e.g. you could fill a pothole with the cornstarch-water solution, that way it would mold to the proper shape like a liquid, but would become firm when a car drove over it).

The main emphasis here should be that there are materials which can fall outside the traditional classifications of solids, liquids, and gases or deviate from the typical properties that are observed for these classes. The idea of viscosity and its ability to change with pressure in certain materials should be introduced.

6. Connections & Close (5-10 minutes)

Bring the students back together at the end of the lesson. Ask them to update the list that you made at the beginning with some additional properties of solids, liquids, and gases that they learned during the lesson. Use this discussion to emphasize the key terms and their definitions.

After updating the list, go through each property and ask the students to suggest ways that that particular property relates to their lives. Try to come up with a few suggestions for each property.

Leave some time for questions at the end.

Follow Up: After the Presentation

Here are some websites you can check out for more information and activities:

- www.sciencebuddies.org
- www.chem4kids.com/files/matter_intro.html
- http://ga.water.usgs.gov/edu/mwater.html
- www.west.net/~science/co2.htm

ELA activity: Students answer the following prompt: "Write a letter to a friend explaining what you learned about states of matter."

Math activity: Measure the temperature at which certain matter changes states

Standards Connections

California Science Standards: Grade 5 physical science

- Elements and their combinations account for all the varied types of matter in the world. As a basis for understanding this concept:
  - Students know that during chemical reactions the atoms in the reactants rearrange to form products with different properties
  - Students know differences in chemical and physical properties of substances are used to separate mixtures and identify compounds
  - Students know properties of solid, liquid, and gaseous substances

Next Generation Science Standards: Grade 5 physical science

- **Topic**: 5-PS Structure and properties of matter

- **Disciplinary core idea:** 5-PS1 Matter and Its Interactions
  - 5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved
  - 5-PS1-3 Make observations and measurements to identify materials based on their properties
- **Scientific & Engineering Practices**
  - Planning and carrying out investigations
  - Constructing explanations and designing solutions
  - Using mathematics and computational thinking
- **Cross-Cutting Concepts**
  - Cause and effect: Mechanism and explanation
  - Scale, proportion, and quantity