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Fun and Games with States of Matter

Curriculum Unit 16.04.02
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Introduction

I teach a science unit that introduces my second grade students to the properties of solids, liquids, and gases through a number of investigations and experiments. My intended curriculum unit will address this area of content and will support the current curriculum that is in place.

Rationale

Edgewood School is an arts-integrated magnet school with a focus on providing a positive learning environment that encourages inquiry, self-discovery, and independent thinking. This approach to learning inherently allows supports and encourages cross-curricular teaching and embraces all types of learners. Our neighborhood magnet school setting is a rewarding environment, with students coming to school each day from a variety of home circumstances and with differences in academic levels. As a result of these variables, the children have differing levels of background knowledge and life experiences. Reaching students through inquiry and discovery opens doors and minds to learning opportunities.

The purposes for creating this unit are to develop critical thinking skills, to make the current science curriculum more fun and exciting for my primary-level students and to support my students as they explore matter and the transformation of matter through experimentation and discovery. My goal is to create a classroom of eager, confident young scientists.

The study of solids, liquids and gases is a central component of New Haven district tiered science curriculum. It is one of three introductory units of study required for second graders with content delivered through a Science and Technology for Children science kit, which contains lessons and materials for the students to explore. The additional use of games and challenges through this curriculum unit will provide practical understanding and real life applications that will extend beyond the learning they experience through participation with only the science kit.

I intend to use my suggested curriculum unit for students to expand their investigations using a variety of games and challenges. Students will: answer the big question of “What is matter?” as they go on a “matter scavenger hunt”; discover that solids remain solid even if they break apart; challenge other teams in an “amazing liquids race”; investigate popping balloons. After fundamental conceptual learning, the students will be using this gaming approach as a new layer of inquiry and hands-on fun.

Concepts/Content

This unit will help the students understand the scientific principles that affect matter. The students will use scientific inquiry, experiments, and observations to understand different states of matter. The experiments included in this unit will be designed to challenge and expand student comprehension by demonstrating the phase changes that occur around us.

Everything in our world is comprised of tiny particles called atoms. These atoms move around in different ways in solids, liquids and gases. In solids, the particles are packed so tightly together that they can barely move. This allows them to keep their shape. Solids have a definite shape, are more or less rigid and have a definite volume. A steel ball has a distinctive shape and unless force is applied, it retains that shape. The amount of space that the steel ball takes up also remains constant. The particles of a solid are tightly packed together so increasing pressure barely compresses the solid to a smaller volume. [1]

Solids also have properties such as elasticity, hardness, malleability, brittleness, and tensile strength. Elasticity is the ability of a solid to regain its shape and size after having been stretched, compressed or squeezed, or otherwise distorted, a classic example is a rubber band; hardness is the capability of a solid to resist being scratched or dented, such as a diamond; malleability refers to the capability of a solid to be hammered into thin sheets or specific shapes, with the metals gold, iron, and aluminum as examples; brittleness is how easy it is to break a solid by bending it, such as glass or ceramics; tensile strength is an indicator of how much force is required to break a solid by stretching it. These sub-categories can help students learn to sort solids into more specific characteristic groupings.

In the liquid phase, the molecules of a substance can move around more than those in a solid. This allows them to change shape easily. The liquid molecules are not held in a regular arrangement, although they are still very close to each other. Liquids, like solids, cannot be compressed and have a definite volume but because they have just enough room to flow around each other. However, liquids have an indefinite shape: A liquid will change shape to conform to its container. [2]

Liquids flow at different rates. Viscosity is the term used to measure the tendency for a liquid to resist flow. The tendency of a liquid to flow easily is called fluidity. Syrup is more viscous than water, and water is more fluid than syrup. Additional properties include surface tension and miscibility. Surface tension is the tendency of a liquid’s molecules to cohere to other which makes it hard to penetrate the surface of a liquid. Surface tension causes a falling drop to assume the shape of a ball, or allows an insect such as a water strider to walk on water. The ability of one liquid to mix with another is called miscibility.

Gas particles have a great deal of space between them, have high kinetic energy and can spread out indefinitely. If confined, a gas will expand to fill its container. Gas molecules have enough kinetic energy to

overcome intermolecular forces that hold solids and liquids together, thus a gas has no definite volume and no definite shape. [3] Most gases are invisible to us, like the air we breathe.

Although this unit does not include investigation or understanding of a fourth state of matter, it bears mentioning to support a complete overview. Plasmas are a lot like gases, but the atoms are different because they are made up of free electrons and ions of an element such as neon (Ne). Natural plasmas are not found that often, but we are familiar with man-made plasmas most everywhere. Fluorescent light bulbs are an example of this state of matter. They are not like regular light bulbs – inside the long tube is a gas. Electricity flows through the tube and acts as an energy source, ionizing the gas. This charging and exciting of the atoms creates glowing plasma inside the bulb.

Another important concept to understand is that substances can change from one form to another when energy is either added or taken away. When water loses energy, it cools down. When liquid water reaches the freezing point (0 degrees Celsius or 32 degrees Fahrenheit), the particles stop moving and it turns into a solid – ice. When water is heated, adding energy, the molecules move faster and spread our farther. This is called evaporation. Clouds are made when water evaporates. However, when the air gets colder and loses energy, the gas, called water vapor, turns back into the liquid we call rain. This process is called condensation. On Earth, frozen water is always melting, liquid water is constantly evaporating to the sky, and water vapor is falling back down again as rain or snow. This process is called the water cycle. It is important to remember that matter can change from a solid to a liquid to a gas and still be the same matter. [4]

A general way to present this process is to fill several ice cube trays with water and add a drop of food coloring to each cube the day before science class. Freeze the cubes until they're solid, and then place one in a zip-top bag, enough for each student to have one bag. Students can identify what state of matter the ice cubes show, and then tape the bags to your classroom window. Over the course of the day, have students observe what's happening in the bags. First, the ice cubes will change from a solid to a liquid, and then the liquid will start forming water vapor, which is a gas.

One way to show second-graders how gas -- in this case water vapor -- changes to a liquid by placing a glass of ice water on the desk. Over the next few minutes, the ice will cause water to condense on the sides of the glass. Show the process of liquid changing to a gas, called evaporation, by leaving the glass of water on the desk for several days. Have the students observe how the water level drops as passes. If it rains, your students can also witness evaporation in action by watching the puddles dry up as the sun comes out and the rain stops.

Changing Phases

Phase describes a physical state of matter. Things move from one phase to another by physical means, such as been mentioned, if energy is added (temperature increase) or taken away (temperature decrease), a physical change can be created.

Phase changes occur when certain temperatures are reached. Sometimes a liquid will transform into a solid, and sometimes it is the other way around. Scientists use something called a freezing point or melting point to measure the temperature at which a liquid turns into a solid, or the temperature where a solid turns into a liquid. There also are physical effects that can change the melting point. Pressure is one of those effects. When the pressure surrounding a substance increases, the freezing point and other special points also go up. It is easier to keep things solid when they are under greater pressure. Generally, solids are denser than liquids because their molecules are closer together. The freezing process compacts the molecules into a

smaller space. Water is a bit of an exception. It is special on many levels. It has more space between its molecules when it is frozen. The molecules organize in a specific arrangement that takes up more space than when they are in the liquid state. Because the same number of molecules takes up more space, solid water is less dense than liquid water, and therefore ice cubes float.

A material may change from solid to liquid or gas to liquid if the temperature is increased. The temperature of a material determines its state, with different materials changing states at different temperatures. The temperature corresponds to the movement of the molecules within a material. The higher the temperature gets, the faster the molecules move. When enough heat is applied to the vibrating molecules of a solid, they vibrate faster, eventually moving farther apart and breaking the forces that hold them together. When this happens, the molecules move freely and the solid becomes a liquid. If enough additional heat energy is applied, the molecules move faster still and separate even more, causing the liquid to change to a gas. [5] The reverse will happen if heat is removed and a material is cooled to the temperature that causes its molecules to slow down. The temperature at which molecules slow down or speed up enough to change the state of a particular material depends upon the type of substance being heated or cooled. As noted earlier, water will freeze and become solid at 0 degrees Celsius, but ethylene glycol, an odorless, colorless, syrupy liquid used in antifreeze in cars and other engines, freezes at -13 degrees C. [6]

A material may also change state if the amount of pressure exerted on the molecules changes. For example, in order for liquid water to become gas, or evaporate, the water molecules must move fast enough to move away from each other and to move into the air molecules above. Therefore, the air pressure has an effect on the water molecules. At sea level, a square inch column of air straight up to outer space weighs about 14.7 pounds. At sea level, this column contains a lot more air than it does at a point much higher up and closer to the atmosphere, such as the top of a tall mountain. Therefore, there is more air pressure pushing on the water molecules at sea level than there is on top of a mountain. With less pressure, the molecules are able to move more freely at lower temperatures. In fact, at 90,000 feet above sea level, water would boil at room temperature. [7]

When a solid become a gas, the process is called sublimation. The most common example of sublimation is dry ice. Dry ice is solid carbon dioxide (CO_2). When dry ice is left out in a room, it just turns into a gas. Coal is another example of a compound that will not melt at normal atmospheric pressures. It will sublimate at very high temperatures.

Deposition occurs when a gas becomes a solid without going through the liquid state of matter (this is the opposite of sublimation). In this area of the country, there is often frost on winter mornings. Those frost crystals on plants build up when water vapor from the air becomes a solid on the leaves of plants. [8]

The list below summarizes these processes:

Fusion/Melting	Solid to Liquid
Freezing	Liquid to Solid
Vaporization/Boiling	Liquid to Gas
Condensation	Gas to Liquid
Sublimation	Solid to Gas
Deposition	Gas to Solid

When studying matter, both physical and chemical properties need to be examined. Physical properties can

be observed without altering the composition of matter – color, shape and tendency to flow are examples of physical properties. By contrast, chemical properties can be observed only when the chemical composition of matter is changed – for example, iron and oxygen interact, rusting occurs and the chemical properties of the iron are changed.

Density is a measure of how tightly things are packed together. It is given by the mass found in a certain amount of space or volume (D=m/V). Imagine a solid cube that is one centimeter tall, one centimeter wide, and one centimeter long. If that cube is filled with Styrofoam, it is light. If it is filled with lead (Pb), it is heavy. The lead is heavier because it has a higher density than Styrofoam.

Investigations, discussions and questions to incorporate with instruction as the students develop understanding: Why do ice and wood float, but rocks and metals sink? Why do helium balloons and hot air balloons float, but normal balloons that you blow up yourself do not? This could also lead to the distinction between mass (or weight) and density. Low density objects like wood fall just as fast as high density objects such as rocks which weigh more (feathers and Styrofoam fall more slowly due to air resistance and not due to their low density).

Strategies/Methods

Research in learning suggests that it is important for the teacher to discover what the students know – or think they know – about a topic at the start of a new unit. This provides a opportunity for accurate conceptions to be validated and reinforced and misconceptions identified and corrected. Before beginning the unit, focus the students' thinking by raising these questions for them to consider throughout the learning and investigation. These reflect the key ideas and concepts presented in the unit. Some guiding questions to use for pre-assessment and to set the stage for learning:

- Does all matter take up space?
- What are the three states of matter?
- What are the properties of each state of matter?
- What form of matter keeps its shape?
- How can you change the shape of a solid form?
- Is a solid always hard?
- How does a solid change volume (space it takes up)?
- Can you name two states of matter that do not have a definite shape?
- Does that same amount of liquid when placed in different shaped containers change in volume?
- Do all types of liquid flow (pour) and the same rate (speed)?
- Can you change the shape of a liquid?
- Can you change the shape of a gas?
- Does gas have a set volume?

This curriculum unit will vary to reflect the learning styles of all students. Included will be:

Experiential Learning: The major strategy for this unit is to engage the students in hands-on learning within their environment. I want them to be actively participating as scientists. The research activities and games

will be designed to be exploratory for the students so they are engaged in the enjoyment of the process as well as the products, visuals and charts for our classroom. The activities included in this unit all include students participating in part or the whole of the experiment or data collection.

Differentiated Instruction: The students will use a variety of approaches, working sometimes individually and sometimes in small groups, determined by the complexity of the activity. Because these are young children with varying levels and background, guidance and pacing will need to be closely monitored, particularly moving about and learning new understanding. In general, any small groups are determined by the teacher to balance the learning outcomes. Specifically, in this unit, students will be grouped accordingly in activities one, two and three.

Cooperative Learning Groups: The students will be given opportunities to work as cooperative groups or teams to complete the games and challenges. This strategy will allow students to work collaboratively taking on various roles necessary to complete the work, with a focus on success for all. Similarly to differentiation, a balance of workload helps all students acquire the concepts from the games or challenges. Know student strengths is important for these groupings.

Focus questions for assessing comprehension include: What is the difference between a solid and a liquid? Why do solids keep their shape? Why don't liquids keep their shape? Why do liquids pour and flow? Why does ice melt? What happens when a liquid reaches its freezing point? What happens when a liquid reaches its boiling point? What happens when a solid reaches its melting point? What is evaporation? What does it have to do with clouds in the sky?

Classroom Activities

Activity One: Matter Scavenger Hunt

Read *What is the World Made Of? All About Solids, Liquids, and Gases?* by Kathleen Weidner Zoehfeld to the class. Students will take their recording sheets and clipboards for a scavenger hunt in three places available to us – the classroom, the cafeteria, and the playground. For the duration of the school day, students will record the solids, liquids and gases they observe. The following day, their information will be consolidated and transferred to a large chart to post in the classroom for the duration of the curriculum unit. New information can be added as students discover new things.

This chart should be available for students to use throughout the duration of the unit and will be important as a reference tool. Other charts containing results from further investigations and discoveries should be added to the classroom, again to keep the information in front of the students and accessible for spelling and a content acquisition.

Example Recording Sheet:

Write or draw examples of the states of matter that notice today. Use the information we learned about in the book, *What is the World Made Of?*		
SOLID	LIQUID	GAS

Activity Two: Solids Remaining Solid?

Have the students view *Bill Nye The Science Guy Phases of Matter* video found in various places online. During the video, Bill Nye shows many examples of solids being compressed and changing shape. Although the entire video is 32 minutes long, the information that students need for this lesson is presented within the first 10 minutes or so. Preview the video to determine how much to use for background information for the class.

This lesson, as a connection to the video, will allow students to experiment with compressing solids and observing any changes. Do they remain as solids as they change shape? The solids students will use for this investigation are foods they enjoy!

You will need: Trays, gallon sized zip top bags, plastic toy hammers, small wooden blocks about 4”x 2”x 2”, graham crackers, cookies, bread, cheerios, pasta

Place a small supply of each item in separate bags and close tightly. Teams of 2-3 students can take turns compressing first with the wooden block, and then with the toy hammer. Students can draw the before-and-after images of what they see in each bag. Are the contents of each bag still solids? How can you tell? What do you know about solids that helps you know the answer? Responses should include: that they still have the properties of a solid, a definite shape, smaller pieces. The responses should be charted on a classroom poster and before and after photos taken to refer to later.

Use the graham crackers and cookies for topping on ice cream or yogurt for a treat after the experiment!

Activity Three: Amazing Liquids Race

This experiment will demonstrate viscosity of a liquid, otherwise known as its tendency to flow.

You will need: Corn syrup, dish soap, honey, maple syrup, 2 pans (one cookie sheet, one pan with deeper sides such as a brownie pan or tray to catch the liquids), tape, ruler, plastic wrap, small cups or dishes to hold 3 tablespoons worth of each liquid, timer

Students will predict, based on their understanding of viscosity or thickness of liquids, which test liquid will travel the slowest down the paper to the marked finish line.

To set up the experiment, measure 12” from one end of the paper, drawing a line from side to side to create a finish line. Tape the paper to the back of the cookie sheet. Over the paper, tape a piece of plastic wrap to cover the entire paper. This plastic wrap will be replaced for each trial run of the various liquids.

Now the race is ready to begin. Place the racing pan vertically inside the deeper pan. Pour one liquid from the very top of the pan and time it as it travels to the line 12”down. Record the time, replace the plastic wrap, and test the next liquid. Retest each liquid 2 more times for a total of three trials for each liquid. Students should create a table to chart the three tests in this manner:

	Trial 1	Trial 2	Trial 3
Corn syrup			
Dish soap			
Honey			

Maple syrup

As a follow-up to this race, use a different set of liquids. These trials can be performed on another day or with a smaller group of students as an enrichment activity. Suggested groups of liquids are olive oil, vegetable oil, baby oil as one set and three brands of shampoo to discover any difference in a similar product. Performing races with thinner liquids is a bit trickier to time but could be fun if students are quick enough with the timer.

Activity Four: Popping Balloons

This activity will demonstrate that air, a gas, takes up space and when contained will cause pressure to build.

You will need: 20 – 30 balloons, all the same size, lots of air to blow them up

Begin by asking students if they have ever seen, heard or been able to pop a balloon. (Some students may not want to participate). Present 4 balloons of the exact same size but that have been blown up to different levels – approximately ¼, ½, ¾ and full. Ask the students to predict which balloon will be the easiest to pop and why they think that is so. The game for this lesson is modeled after the old fashioned game of running across a distance and then sitting down on a chair and on top of the balloon to pop it. Students will discover that the balloons inflated on ¼, ½ and ¾ are quite difficult to pop. The balloon just seems to roll around. The air inside (the gas) is not stretching the surface of the balloon enough to keep it still enough to pop. Those with more gas inside stretch the balloon, making the surface thinner and easier to pop. This game will show the students that, although we cannot see the air we breathe, once we contain it inside the balloon, we know it is there. And since balloons are rubbery, they will stretch. Ask students whether they think air might be in places that don't stretch. Is there air in a jar or bottle? Can we capture air on other containers? How do we know if we have? Students will begin to understand that air is everywhere – we know that because we are able to breathe it even if we cannot see it!

Repeat this game so that all students are able to use balloons that are inflated to capacity. Everyone that wants to should have an opportunity to pop a balloon to experience the air leaving the balloon and deflating it back to its original size.

Activity Five: Crayon Melting / Solids – Liquid – Solid

This activity some changes caused by heating and cooling can be reversed.

You will need: a collection of broken crayons, clear cups for sorting, electric hot plate, low pan, foil cupcake liners, tongs, candy molds from craft store (small shapes such as stars, numbers, shells)

Students will see the crayons change from solid to liquid and back to solid in a new shape.

The students will peel the crayon pieces and sort them into large clear cups labeled with general colors – blue, yellow, red, green, purple, orange, black, gray (whites can go in this cup). After sorting is complete, the next step is to melt the crayons by color. Students are observers as the teacher handles this part of the procedure.

Arrange the candy molds so they are ready to be filled. Place the pan on the hot plate and fill it 2/3 with water. Place the foil cups, 3 at a time, in the water. Turn the heat to medium and fill the foil cups with 3 different colors. As the water heats up, the crayons will begin to melt. Students will be able to observe that during the melting process some crayons remain solid as others melt more quickly. Why might that happen? Eventually all the crayon pieces will melt and the mixing of slight color differences will be noticeable – for

example, lighter greens with darker greens. Using the tongs, lift the cup of melted crayons out of the pan and pour the liquid into the candy molds to create the new shapes. It's easy to over-fill so pour slowly.

It is important to practice this lesson prior to actually doing it with the students for a number of reasons: learning to manage the pouring, gauging how many crayons to melt at a time, and testing how long the liquid takes to cool and become solid again. Making a number of new crayons ahead of time will create a supply for students to all have a collection of colors and shapes.

Students can now use the new set of crayons to draw and color three examples each of the states of matter. With examples on the classroom charts generated in Activities One, Two, Three and Four, students should be able to show their understanding of the states of matter. An example of a simple worksheet follows.

SOLID LIQUID GAS

End Notes

1 Shipman, 116

2 Shipman, 117

3 Shipman, 117

4 William K.Esler and Mary K. Esler, Teaching Elementary Science, 11.

5 www.chem4kids.com/files/matter_states.html

6 Carolina Press, 15

7 www.chem4kids.com/files/matter_states.html

8 www.chem4kids.com/files/matter_states.html

Reading List

Donovan, Suzanne, and John Bransford. *How Students Learn: Science in the Classroom* . Washington, D.C.: National Academies Press, 2005. As the title suggests, this book helps explain how leading educators present science curricula to maximize learning. Specifically helpful were the elementary examples.

Epstein, Lewis C. *Thinking Physics: Understandable Practical Reality* . San Francisco, CA: Insight Press, 2002. A good beginner's guide for teachers that answers some basic physics-related questions. Written in an easy-to-understand way.

Carolina Press. STC Teacher's Guide: Liquids and Solids. Burlington, NC: Carolina Biological Supply Company, 2005. This is the current district curriculum that provides the fundamental concepts and principles for second grade students. The text is available on

line.

Esler, William K., and Mary K. Esler. *Teaching Elementary Science: A Full Spectrum Science Instruction Approach* . Belmont, CA: Wadsworth, 2001. This is a very comprehensive text with lots of examples of instruction and techniques across many science content areas.

Pearce, Charles R. *Nurturing Inquiry: Real Science for the Elementary Classroom* . Portsmouth, NH: Heinemann, 1999. Great examples and ideas of how to incorporate daily opportunities for students to explore, investigate and discover in the science classroom.

Shipman, James T., Jerry D. Wilson, and Aaron W. Todd. *An Introduction to Physical Science,* 12 th Edition (Cengage, New York, 2009)

www.chem4kids.com/files/matter_states.html. Great website for teachers and students to learn fundamental science vocabulary and examples.

Zoehfeld, Kathleen Weidner., and Paul Meisel. *What Is the World Made Of?: All about Solids, Liquids, and Gases* . New York: HarperCollins Publishers, 1998. Good examples of the states of matter and some basic activities to demonstrate the attributes of each. Level 2 reader.

Appendix – Implementing District Standards

Next Generation Science Standards for Grade Two include understanding the Structure and Properties of Matter. This unit satisfies the following standards:

2-PS1.1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

Students will be classifying and describing a variety of solids, liquids and gases throughout the five activities included in this unit. Most specifically, the final activity serves as an informal assessment of their understanding of the properties of the three states of matter.

2-PS1-2. Analyze data obtained by testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Students will be conducting an experiment using liquids and gathering data to determine the properties of those particular examples. They will determine if the viscosity of each is helpful for its use and function, for example, shampoo. They will be running a series of trials with sets of materials and determining their similarities and why they might have the particular properties.

2-PS1-4. Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.

Students will be melting solid crayons to liquid wax and cooling it back to a solid. They will see that heating and cooling in this case can be reversed – crayons will return to solid form after cooling.