Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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# Fluid Thinking about Liquids and Solids

Curriculum Unit 09.03.10
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## Introduction: Objectives and Rationale

The purpose of this unit is to develop critical thinking skills, make the science curriculum more exciting for students, incorporate the scientific method, and encourage students to make connections between school science and real life. It is designed for second grade, for which the study of liquids and solids is an important aspect of the science curriculum. This is one of four units of study required by the district and incorporates the use of an STC (Science and Technology for Children) science kit, which contains suggested lessons and materials for the students to explore. The study of kitchen science will add in-depth understanding and real life applications that go beyond the learning they achieve through participation with the science kit.

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 exceptions and changes that apply to the traditionally defined categories of liquids and solids. Furthermore, learning about the science of the kitchen will allow students to apply their learning in the classroom to everyday materials they see at home.

This unit is designed for second grade at Davis Street Inter-District Magnet School. The school is a "Title 1" school with a majority of its student body comprised of families from low socioeconomic background. Since many of the students lack the extracurricular experiences their suburban counterparts enjoy, there is a great need to provide interesting lessons that actively capture their attention while they are in school. It is especially important to teach science in an engaging way that will inspire students to think critically and prepare them for more advanced science and state mandated testing of science in their near academic future.

There has been a great emphasis recently on reading and writing in order to address a need to improve scores on state-mandated tests, so the science activities need to be integrated with the literacy curriculum. Therefore, this unit will incorporate the use of second grade reading material for students to learn from and respond to. They will read and write about the various states of matter and the physical changes matter goes through. The students will always be required to write about what they have observed. Writing helps students to remember and reflect on what they have just learned and how their understandings have developed over time. The integration of science with language arts and other subject areas, as well as the hands-on nature of

the activities included, will activate the various learning styles and academic strengths of individual students. Therefore, this unit contains writing and reading comprehension activities that correspond to the objectives of the required literacy curriculum.

This curriculum unit is designed for second grade students, but the content could easily be extended to teach students from second to fifth grade. In order to adapt the curriculum for older children, the reading selections might be supplemented with more challenging and longer texts. The students could delve much deeper into terminology and learn more about the scientific principals. They would be expected to write with much more depth, but the content would be very similar.

The unit will consist of two main sections. The first section will provide various opportunities for students to sort and observe various properties of solids and liquids. The second section will provide hands on experiments to challenge some of the generalizations they may have made during the first section. The experiments will help students to understand how liquids and solids react under certain circumstances. Students will understand how energy affects matter and they will begin to understand how the movement of molecules affects the materials we see, touch and eat. The students will have opportunities to observe situations in which solids can be made to flow and act like a liquid, as well as observe situations that create changes in state from solid to liquid or vice versa. The students will use foods and other familiar materials to make these observations. This unit will provide multiple opportunities for scientific inquiry, and will leave students with both questions and answers. Group and class discussions will follow each experiment to address and correct assumptions and misunderstandings. The activities will address several New Haven Science Standards, as noted in Appendix 1.

## Background Knowledge

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### Liquids and Solids

Liquids and solids are states of matter, which correspond to the energy and movement of the molecules that make up the materials. A great introductory lesson that will help the students to understand this can be found at http://www.msm.cam.ac.uk/SeeK/solid.htm. This fun lesson will have students acting out the movement of the molecules for different states of matter

The students will learn initially that solids are objects or materials that have a definite shape and do not flow, nor take the shape of their container. A solid typically is a material in which the molecules are close together and usually arranged in a defined pattern. The molecules in a solid vibrate, but do not have space or energy to move around each other or from one place to another [1] When you drop a solid, it remains the same shape. In order to change the shape of a solid, you would have to cut it or apply strong pressure. Some examples of solids that the students will examine are apples, cold butter, pickles, carrots, sweet potatoes, hard candies, chocolate bars, ice cubes, and hard boiled eggs, which can all be changed by slicing or cutting them. The students will explore this concept by dropping the objects and then cutting them into new shapes or observing as the teacher does this with a sharp knife. Some of the materials can be changed by applying pressure, or smashing them. The students might find it fun to change the shape of cold butter or chocolate bars by hitting them with a hammer. They should notice that although the solids change shape in these ways, they still do not flow under more gentle forces, like gravity. The students will also examine solids that are too small to

easily change in these ways, such as individual grains of rice, sugar, and salt.

Students will initially learn that liquids flow and take the shape of the container they are in. Liquids can also be defined as materials in which the molecules are close together, but not arranged in a definite pattern, and in which the molecules move around and pass each other slowly. When energy is added to a solid material, usually in the form of heat, the molecules move more quickly than the vibrating molecules of a solid, and can spread out. This changes the solid to a liquid and allows the material to flow. Some examples of liquids that the students will examine are syrup, soda, vinegar, orange juice, and milk. The students will move them from one container into containers of various shapes to observe (and enjoy watching) as the liquids change shapes.

**Changing Phases of Matter**

A material may change from solid to liquid or gas to liquid if the temperature is changed. The temperature of a material determines its state, although different materials change state 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 and separate even more, causing the liquid to change to a gas [2]. 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. For example, water will freeze and become solid at 0 degrees Celsius, but salt water freezes and becomes solid at -2 degrees Celsius [3].

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, the water would boil and begin evaporating at room temperature [4]. In the classroom, the students would not be able to observe the effects of differences in air pressure, but could write stories and draw pictures to demonstrate that they understand the teacher's explanation.

**Neither Liquid Nor Solid**

Several substances defy classification as liquids or as solids, including certain types of solutions and suspensions. The students will create and examine some of these substances including simple suspensions, colloids, and gels, using materials found in the kitchen. They will then discuss and write about how these foods are different from typical solids and liquids.

Suspensions are mixtures between two substances, when a second material is divided into tiny particles and spread out thoroughly within the first substance [5]. The first kind of suspension the students will examine is made up of solid particles mixed evenly into a liquid. This cannot easily be classified as liquid or solid, since the observer can detect both solid and liquid parts if looking closely. The particles are often possible to see

with the naked eye, and are otherwise visible with the use of a microscope. The solid particles in this type of mixture can sometimes separate out if left to rest long enough and then settle, or if filtered out [6]. Examples of common suspensions found in the kitchen are flour mixed in water, orange juice pulp dispersed in orange juice, and milk. If the first two were left to sit overnight, the solid flour particles and orange pulp particles would settle to the bottom of the containers.

One interesting type of suspension is a colloid. A colloid is a mixture that is not truly homogeneous, but appears homogeneous to the naked eye, and cannot be separated or filtered out easily. The particles and the substances they are spread within may be solid, liquid, or gas [7]. For the purpose of this unit, the students will observe colloids in which a liquid is permanently or semi-permanently mixed within another liquid that would not normally mix with it to create a solution. One of the liquids will form tiny droplets that will be surrounded by the other. When the two normally immiscible liquids are forced to remain mixed as a suspension, it is called an emulsion. The liquids become inextricably mixed, or emulsified, by incorporating the second liquid a little at a time and/or with use of an emulsifying agent, such as egg yolks. The emulsifying agent is also called a surfactant. The molecules of a surfactant have one end that likes to be attached to the molecules of one liquid, such as oil, and one end that likes to be attached to the molecules of the other liquid, which is usually water [8]. Examples of emulsions are mayonnaise and (homogenized) milk. The students will examine and discuss the texture of the mayonnaise emulsion, which they will make. They will see that it does not easily flow, but does not truly keep a definite shape either; the shape depends on how hard you push on it or how long you allow it to sit in its container.

Students will also examine another interesting substance called a gel. The students will create gels in which solid particles are evenly dispersed within a liquid. Examples of gels are gelatin and cheese [9]. The students will make and examine a gelatin fruit mold. The prepared gelatin will have similar properties as the mayonnaise, since it neither flows easily nor keeps a definite shape. The gelatin comes closer to the definition of a solid, however, since it will take much longer to flow and will keep a more definite shape until harder pressure is applied. The students will compare and contrast these substances in writing and discussion.

**Explanation of Teaching Methods**

*Literacy Component*

Students will read, study and discuss information about states of matter, molecules, and liquids and solids. After the information has been discussed, reading comprehension questions will be modeled, discussed and answered in writing. Some of the reading will be teacher-created, as will the written response questions. This reading material will be on a level the students can read together with the teacher and/or peer support. The written response questions will match the literacy curriculum focus. The students will also read children's science books that pertain to the subject of matter, molecules, and physical changes to matter. A selection of books at the students reading level will be provided for them to read and respond to in writing. A selection of titles for these activities can be found in the Children's Classroom Reading Selections section. A sample written response activity sheet can be found in Appendix 2.

*Experimentation*

The students will sort and compare various solids, then liquids, and create observation logs that reflect what they notice and learn. The students will compare liquids to solids and try to make generalizations and define these properties. Students will cause changes in the states of matter through traditional experiments and

cooking lessons, while utilizing the scientific method. This section will address the New Haven science performance standards for scientific inquiry numbers 1-7.

*The Scientific Method*

The Scientific Method is a system of steps by which scientists use knowledge and reason to figure things out [10]. It consists of observation, questioning, hypothesis, experimentation, discerning the results, and finally discovering the applications of the experiment. Observation means examining information with all the senses and sometimes includes reading or listening to learn what other people have said about their observations. Sometimes observation requires special tools, such as magnifying lenses, microscopes, thermometers, measuring tapes, etc. [11] The Scientific Method begins when students use background knowledge and observations to form a question that they want or need to find a scientific answer to. A scientific answer is an objective result that others can replicate and test for themselves, rather than relying on the thoughts and opinions of another person. Next, students use background knowledge to form a hypothesis, which is an educated guess, or the answer they think the experimentation will show. Then, it is important to carefully design (or find) an experiment that will help answer the question. The teacher and/or students devise a specific procedure, which must be written out and followed carefully. The students carefully conduct the experiment and analyze the data from the experiment. Analyzing the data involves observing exactly what happened and recording measurements, time, etc. Then, the experiment has to be examined for limitations, or factors other than the intended variable, that might have affected the results. For example, some experiments might be affected by factors that are difficult or impossible to control, such as the air in the room or the subjectivity of the observer. Therefore, a good experiment should be replicated to check for validity, and may need to be refined by changing the procedure slightly until uniform results can be achieved over several trials.

## Getting Started: Becoming Scientists

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One of the main goals of the unit is to encourage students to think critically and think of themselves as scientists. Therefore, the children will need to use the Scientific Method to problem solve. First, the teacher will make a chart to creatively display the students' ideas and fill it in by asking the students to say and write words they associate with scientists. This will be followed by a shared reading lesson using a passage about the scientific method. A great selection to use in second or third grade can be found in the book, Bill Nye The Science Guy's Big Blast of Science, by Bill Nye. The teacher will use the overhead projector (or photocopies) to make the reading selection accessible to all students. He or she will read aloud as the students read along silently or aloud in unison. The reading will be interrupted by discussion of key words, such as reason, controlled, etc. and followed by questioning to verify that the passage was understood. This passage will be reread and discussed over the span of two or more days, so that students will have a chance to read, understand and discuss it. Then, the students will write a paragraph to answer a question to show their understanding, such as "Would you want to use the scientific method to solve a problem in your own life?" The students would then answer, giving information about a specific problem or question in their own life that would or would not be solved this way. After the students have learned about what it means to be a scientist, they should revisit their scientist idea chart to see what they have learned and revise any misconceptions they may have had.

The class will then be ready to learn about liquids and solids. First, the teacher will help the students make a KWL chart, which will show what they think they Know about solids, what they Want to know, and leave room for what they will have Learned at the end of the unit. The students may suggest ideas such as "solids are hard" and "solids don't move by themselves." The teacher will demonstrate the difference between a liquid and a solid by putting an apple in a clear container and then moving it to several other clear containers with different shapes. He or she will repeat this with apple juice, pouring the juice from one container to the next. The students will observe that the juice takes the shape of each container while the apple stays the same shape. [12] The students will notice that the juice flows and the apple does not. This demonstration will bring the students closer to the working definitions they will use during their initial explorations of solids and liquids. Of course, they will ultimately challenge these definitions and examine liquids and solids more closely through additional lessons and experiments later in this unit.

Based on the previous demonstration, the teacher will then display at least twenty different materials and ask the students to identify which are solids and which are liquids. The materials to display (which can be found in the STC science kit, as directed by Carolina Biological Supply Company.) are shampoo, water, oil, corn syrup, a wooden cube, a clear plastic cube, plastic condiment lids, rubber balls, a small metal ball, two types of plastic spoons, a small wooden golf tee, a small gem stone, a crayon, a ping pong ball, a metal nut and a silver metal washer, a brass washer, a small pipe cleaner, a small cork, a bobby pin, a square magnet, a button, a paper clip, a sponge, and a clear plastic cylinder. The teacher will assign science buddies and put away the liquids for later in the unit. He or she will then provide each pair of student buddies a large container with 20 different solids to examine.

## Examining Solids

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Students will conduct a series of sorting lessons that will help them to observe various properties of solids. After each experience, the students will create a journal entry describing what they were looking for, what they observed, and anything interesting they noticed. They will also have to create labeled drawings to show what they did with the materials they observed. A sample log page can be found in Appendix 3.

For the first activities with solids, students will sort all twenty objects, such as a clear plastic cube, a red, wooden golf tee, and a metal ball by color and then by shape. Of course, they will record their observations with pictures and labels in their science journals.

After sorting by these familiar attributes, the students will examine the objects to see whether they roll or stack. They will use a Venn diagram to keep track of their findings [13]. For this activity, the teacher will draw the two interconnected circles to make a large Venn Diagram on a sheet of paper at least 36" by 20" with the left circle labeled "rolls," the right circle labeled "stacks," and the middle overlapping area labeled "both". Then, he or she will instruct the children to test the objects and place them on the Venn diagram in the appropriate spot. (Objects that neither stack nor roll should be placed on the paper outside the Venn diagram.) The children will discover what each solid object does and write and draw their findings in their science journals. Then, the teacher should display the shampoo, water, corn syrup and oil. Students should be given droppers to test drops of the liquids for their ability to stack or roll. The students will discuss why the liquids are not able to stack or roll and write their observations in their journals before cleaning up.

For the next activity the students must arrange the objects in a continuum according to their hardness, from the softest item to the hardest [14]. The students will learn that it is often important to describe objects in comparison to others in order to be specific. They will realize that solids can be hard or soft and yet retain or regain their shape after the pressure is removed. They will describe the objects as specifically as they can and distinguish a soft solid from a liquid. At this time, it might be helpful to demonstrate the difference between a soft solid and a liquid, using a sponge ball and a water balloon. The teacher will gently toss the water balloon and sponge ball in the air and allow students to squeeze and examine each. Then, he or she will drop both items on the floor, which will cause the water balloon to break and the water to spill all over the floor. The students will notice that the sponge ball retained its original shape after being dropped while the water, which had taken the shape of its water balloon "container" has now taken the shape of the floor [15].

**Expanding Knowledge of Solids with Food**

To expand their experiential learning and further excite the students about learning the properties of solids, the teacher will revisit the previous activities using objects from the kitchen. First, he or she will display the following familiar items: cold butter, rice, pickles, carrots, sweet potatoes, hard candies, chocolate bars, ice cubes, hard boiled eggs, vinegar, pancake syrup, orange juice, milk, soda, sugar, salt, frosting, mayonnaise, egg yolks, and uncooked bread dough. The students will have to examine each item and identify which of the items are solids. The children will do this by listing the names/pictures of the items on a three- column chart labeled solid, liquid, and unknown. Based on the definition that a solid has a definite shape of its own, and the sorting and observing they have done so far, the students are likely to choose the first nine items. Perhaps they may decide to include the salt and sugar as well. If no one does, the teacher might challenge the students to consider whether they should be sorted according to one grain or the whole amount as one item. If it doesn't happen automatically, the teacher will also encourage the class to consider whether the frosting, dough and mayonnaise should be considered solids. They will discuss the circumstances under which they act like solids or act like liquids.

After experimenting with several of the foods, they may realize that a substance might be considered a solid or a liquid depending on how long you let it sit or how hard you push on it. For example, the bread dough does not immediately flow and fill up the container it is in, but it will eventually spread out over time. Similarly, if you push the frosting or dough into a certain shape, it would not resist and go back to its original shape like a sponge or a rubber ball would. They will continue discussing and debating as necessary until an agreement is achieved among the class members. After the students have come to an agreement, then they will examine and sort them according to their color, shape and whether they roll or stack.

After the science teams have had a chance to sort by the various properties and arrange their solids according to hardness, they will share with the class and discuss any differences among the answers that were found. The teacher will create a chart showing the final results of each activity for the class to view and refer to. Of course, the students will also draw and write about each of these experiences in their science journals. Please note that the students should be advised not to consume any of the science materials unless they are given explicit permission to do so. Students will utilize disposable trays and newspaper to contain any mess that may be produced by these activities.

Next, the students will experiment with all of the original household objects and the additional kitchen materials in whatever way they would like to for ten minutes. Then, they will play sorting games in which one partner sorts by a mystery rule and the other must guess the rule [16]. The students will continue to keep journal entries describing each of these experiences.

Then it will be time to challenge some of the assumptions the students have. The students will already be noticing and commenting that the ice cubes have started to melt by the end of the sorting activities and therefore are changing into liquid water. The teacher should encourage the students to consider what might cause some of the other materials to change their state as well. He or she should also encourage the class to discuss their experiences with food and to share their background knowledge, such as watching melting butter on a warm day or seeing it melt in a pan as part of a recipe.

The students will now look closely at the rice, salt, and sugar. They will use magnifying lenses to identify the small grains of salt and sugar and discuss how these substances would be categorized according to their shape, color, rolling vs. stacking ability and hardness. Then, they will pour the substances into containers of various shapes and see that they do take on the shape of the container they are in when observed as a group. However, each grain of salt, sugar or rice has its own definite shape. In this case, it depends how closely you look at the substances and the individual particles that they are made up of.

**Examining Liquids**

The students will now examine and compare liquids. They will begin by comparing water, shampoo, and glue. They will stir, tilt, feel and look at them closely. They will compare the way they drip and pour as well as the color, feel and thickness. Then, they will investigate to see how quickly or slowly they flow. They will learn the term viscosity. They will use zip-lock bags to see the fluidity and to see how liquid can take on the shape of the container it is in. The students will perform drop races to see how quickly or slowly the liquids flow [17] . The students will be instructed to attempt to form the liquids into a definite shape and write in their journals about what they observed.

Students will then choose the substances from the kitchen materials I have on display that they think are liquids. The students will undoubtedly choose the syrup, soda, vinegar, orange juice, and milk. Encourage debate and discussion to decide if the sugar, rice, mayonnaise, frosting, and dough should be included as well. After the liquids have been chosen and distributed, students will observe them by touching, stirring, and tilting them. They will then examine them by moving them inside zip-lock bags and conducting drop races. In addition to writing about them in their journals, they will arrange and order all the liquids in several ways to show their observations. They will preserve their observations by drawing them on paper strips. First, the students will sort the liquids by color and arrange them from darkest to lightest. Then, they will arrange them from least viscous to most viscous. Finally, they will arrange them by clarity, from the most opaque, which will not allow light to pass through (glue), to the most translucent, which will allow light to pass through (water). In the latter case, it is possible to look through the substance.

For a fun extension, students will make "magic mud," (which is often called "oobleck") by combining 5 tablespoons cornstarch with 3 tablespoons water and a few drops of food coloring in a mug [18] . The "magic mud" feels solid when strong pressure is applied quickly, but when less pressure is applied, or applied slowly, the "mud" becomes liquid and is able to flow. [19] The students must examine it by pouring, touching, and spreading it inside a zip-lock bag and on a paper plate. The students will have to decide where the magic mud should be placed on the continuums they have created for the liquids they have already arranged. (They will also have to be able to explain why.)

## Extending Learning: Enigmas and Changing States of Matter

Ways to change the state of matter include changing the temperature by adding or causing the substance to lose energy, applying pressure, and changing the chemical properties by adding something to it. The students will now have opportunities to experiment with changing states and creating suspensions.

**Kitchen experiments that change the phases of matter**

The following experiments allow the students to use the scientific method and create a physical change in foods from solid to liquid or from liquid to solid. The teacher may want to create a special "experiment log" for the students to write about each step of the scientific method as they experience it, along with their data, to be placed inside their science journals. A sample experiment log can be found in Appendix 4.

*Changing Solids: Chocolate bars to Chocolate Sauce*

The teacher will begin by gathering the following materials: a medium pot with a long rubber handle and a "double boiler" pot that fits together with the former, several boxes of baking chocolate, a sharp knife (for the teacher to handle), timer, a wooden or rubber spoon, water and a stove or portable burner. Then, the following optional ingredients will be needed for the extension: sugar, vanilla extract, and heavy cream.

The students will have previously examined, stacked and sorted chocolate bars in their exploration of solids. They will also know from experience that chocolate can sometimes take liquid form. Now they will have a chance to make the solid bars turn into a delicious liquid chocolate sauce, but they will have to conduct an experiment first. The teacher will remind the students of the steps they must follow in order to use the scientific method to solve a problem. He or she will then ask the students to use their prior knowledge to predict what will make the chocolate bars change from solid to liquid. Then the class will discuss what happens to chocolate when left in the sun (or a warm room) on a warm summer day. Depending on the children's prior knowledge, the teacher may want to demonstrate chopping, pressing on, and heating the chocolate bars in order for the children to observe that heat causes the change.

The teacher will gather the materials and ask the students to predict whether the size of the chocolate pieces will affect the speed of the transformation from solid to liquid. He or she will lead the students to define a specific question that will allow them to figure this out. The students will record their predictions and reasoning in their journals. Next, the students will brainstorm ideas for testing their predictions. The students will most likely realize that they will need to compare two sets of differently sized chocolate pieces melting over heat. They may not realize that the amount of heat and time must be controlled. This is an opportune time to review the idea of controlling all variables except the one that is being tested. It will be important to explain that the pots must be the same, as well as the amount of chocolate in each pot, and the temperature, leaving the size of the chocolate pieces as the only difference between the two items you will be observing. That leaves the question of how to make sure the chocolate is heated at the same temperature in each pot. Although it is possible to measure the temperature of each with a thermometer, this would only allow the temperature to be checked, but not specifically set in order to make sure it is the same in both pots. Therefore, the teacher will have to lead the children to remember that they know the temperature of boiling water and to discover that boiling water under each pot will ensure that both pots are heating the chocolate at 212 degrees F, the boiling point of water.

These pictures show the set up required before melting.

These show the chocolate pieces before and after melting.

The students will need to time the melting in order to determine how long it takes for each set of chocolate pieces to turn to liquid. The students will have to decide and agree ahead of time whether they will stop the timer when the transformation is complete, when more than half is liquid, or when it begins to melt. They will also have to determine if and when they will stir the chocolate as it melts. Then, they will observe both sets of chocolate and determine which became liquid faster. Together with the teacher, the class will write out the steps of the procedure they have agreed upon. It will also be important to discuss and agree upon how they will determine whether their hypothesis has been proven true or false. In other words, the students should be able to articulate what results they would expect to prove their hypothesis and what results would disprove it.

In order to improve the validity of the experiment, the data should be recorded for multiple trials. This can be done by way of the teacher recording data for each group and compiling it, or by actual repeated trials. The students will probably be happy to repeat this experiment to verify the results. If possible, it should be repeated several times, on more than one stove, in order to prove its universality. The students will record their observations with words and pictures in their journals and/or experiment logs.

When I first conducted this experiment at home, the smaller, ¼ oz. chunks, of chocolate melted in 6 minutes and 1 second, compared to the larger, 1 oz. chunks, which melted in 6 minutes and 15 seconds. Since this was a very small margin, it proved the need for multiple trials. After this, I repeated the experiment, but compared 1 oz. chunks and 1/8 $^{th}$ oz chunks. I further refined my experiment by comparing three sets of chocolate pieces: this time using 1 oz. chunks, ¼ oz. chunks, and 1/8 oz. chunks. As you can see from the data listed below, the smaller pieces always melted faster than the larger pieces, though there was considerable variation in melting times. The teacher might have students try one or more of these variations, and instruct students to conduct additional trials. Subsequent trials might use even smaller pieces of chocolate, such as chocolate chips, or use pieces of chocolate that have been cut differently, such as horizontally. The teacher should also ask the students for ideas of ways to alter the procedure further in order to better refine this experiment.

Trial 1: 6 oz of chocolate each

| size of pieces | 1 oz | ¼ oz | 1/8 oz |
|---|---|---|---|
| time to melt | 6:15 | 6:01 | n/a |

Trial 2: 6 oz of chocolate each

| size of pieces | 1 oz | ¼ oz | 1/8 oz |
|---|---|---|---|
| time to melt | 8:11 | n/a | 4:35 |

Trial 3: 3 oz of chocolate each

| size of pieces | 1 oz | ¼ oz | 1/8 oz |
|---|---|---|---|
| time to melt | 8:05 | 4:15 | 2:30 |

For a delicious extension, the students will make chocolate sauce using the liquid chocolate. Combine 1 cup heavy whipping cream, 1/3 cup sugar, 1/3 cup light corn syrup, 1 and ½ teaspoons vanilla extract, and mix the combination together with 12 oz. hot, melted chocolate [20]. The children may try a spoonful or dip fruit into the sauce.

Finally, the students will form teams according to preference of chocolate sauce or chocolate bars. They will prepare notes in writing and conduct a verbal debate attempting to convince the other team that the liquid sauce or the solid chocolate bar is best.

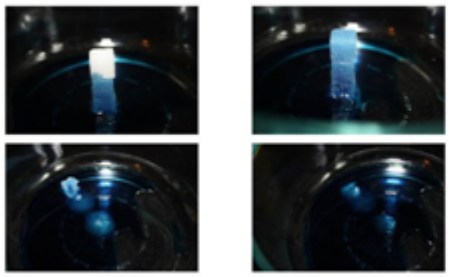
*Changing Solid to a Liquid Solution: Sugar Cubes to Sugar Water* [21]

For the next experiment, the materials needed are sugar cubes, food coloring, water, a tablespoon, a plainly colored saucer, dish or bowl, a timer, and a spoon.

The teacher will display sugar cubes and ask the students to observe them and describe whether they are solid or liquid. He or she will then have them explain why they appear to be solid and ask them to describe them in writing and pictures, according to the criteria by which they examined the other solids earlier. Then, the teacher will pose the problem: is it possible for the sugar cubes to become liquid and how might this happen. He or she will help to define the question that will guide the experiment by asking students to predict what will happen when 3 sugar cubes are stacked and placed on a shallow pool of water. Students will discuss the question in groups and decide on a hypothesis. Then, they will have to explain what prior knowledge helped them to make this prediction. The teacher will then write out the steps of the procedure that the class must follow.

The students will also work in groups to complete the experimentation. The teacher will instruct each group to put a drop of food coloring in the water and pour a tablespoon of water onto a saucer. Then, one of the students will place the stack of sugar cubes on the pool of water. Another group member will keep track of elapsed time and another will be the record keeper. The students will observe and record what happens after 30 seconds, 1 minute and 2 minutes, etc. The record keeper will write the group's observations in a table such as the sample below. Since the water molecules are strongly attracted to the sugar molecules, the water will soak into the sugar and climb up the tower of sugar, causing the sugar cubes to become soggy and fall over. After observing this, the groups will discuss the results and decide whether the sugar is still a solid substance after the water has soaked in. They will have to defend their answers to the class and in their journals.

These pictures show the sugar cubes after 10 seconds, 30 seconds, 10 minutes, and 25 minutes



| | |
|---|---|
| 10 sec. | water rose up 2 ¼ cubes |
| 30 sec. | blue all the way up 3 cubes |
| 1 min. | 3rd cube knocked over |
| 2 min. | 1st cube starting to melt |
| 5 min. | 1st &2nd mostly melted, 3rd ¼ gone |
| 10 min | 1st &2nd almost gone, 3rd ½ gone |
| ... | ...last cube dissolving visibly... |
| 25 min | all melted but a speck, looks liquid |

*Changing Liquids to Solid: Making Ice Pops*

The transformation of liquid to solid that the students may be most familiar with is that of water freezing and becoming solid ice. After studying various properties of the liquids provided to them, the students may be interested in creating solid juice pops from the liquid orange juice. Before they may eat the pops, however, they must conduct an experiment to see if the juice will become solid faster or slower than the water.

For this activity, the materials needed are two identical ice cube trays per group, orange juice, thermometers, timers, plastic knives, a freezer, and water. This activity will also take approximately two hours to complete data collection. It will be important for the students to poke and examine the juice and water at regular intervals, at least every ten minutes. However, since the data can be collected rather quickly at ten-minute intervals, the students may be able to work on another task between data collection duties. When I conducted this experiment at home, the juice and water started to change appearance after less than twenty minutes. The orange juice became more solid sooner than the water, yet the water ultimately formed uniformly solid ice cubes faster than the orange juice. This is because the orange juice has tiny orange pulp particles suspended within it. A selection of results you might expect can be found in the sample data table that follows.

| Elapsed Time | Appearance of water | Appearance of juice |
|---|---|---|
| 10 min | water | orange juice |
| 20 min | slight film of ice over water | mushy, thick, less fluid than water |
| 40 min | ice on top of water | mushy, slushy throughout, not hard |
| 60 min | ¾ liquid with top ¼ of cube ice | mushy, slushy throughout, not hard |
| 80 min | at least top ½ very hard | thick, slushy, not hard |
| 120 min | solid ice cubes | close, but not solid, almost ice |

To conduct the experiment, the students will first need to decide what they will consider solid for the purposes of this experiment and come to an agreement in writing among the class members. Second, they will need discuss their prior knowledge and form a hypothesis. They will predict which liquid will freeze faster, and write their reasoning in their journals. Third, the teacher will lead the class to write a clear procedure. The students will have to make sure that the time is the only variable. Therefore, the teacher will lead the students to discover that they will need to make sure they have equal sized ice cube trays, equal amounts of the liquids, and room to freeze both liquids in the same area of the freezer with equal temperatures. The students will then measure the liquids, examine the trays, and use thermometers to make sure the freezer has equal temperatures in the areas where the ice cube trays will sit. The students will pour the liquids, place the trays in the freezer, and begin timing. Every ten minutes, they will need to examine and poke at cubes of each liquid to make observations and determine the consistency of each substance. The students will record the data at each time interval as they did for the sugar cubes. Finally, the students will record their observations

and speculations about their results in their journals. Then, they will be able to eat the orange pops they have made! As a fun language extension, the students may conduct a debate about liquid orange juice versus orange ice pops, as they did for the chocolate.

*Discovering Special Mixtures: Changing a Gel To a Solid- (Baking Bread)*

Students will have discovered from their previous activities that dough acts like a solid in some ways, since it does not flow unless a force is applied to it. It does not have a definite shape, nor does it completely take on the shape of the container it is in. It is somewhat rigid but can be made to flow or change shape. However, once it becomes bread, it will have a definite shape and definitely will not flow. The students are likely to know that dough must be baked, or heated in order to become bread and take on its solid form. For this activity, the students will experiment to see how long bread dough must be heated before it becomes solid. They should be given dough and bread (made from the same kind of dough) to touch, look at, compare, and of course write about their observations. Of course, they will want to make the dough into solid bread to eat.

The materials needed for this activity are prepared bread and two identical amounts of bread dough for each group, a knife, a heat-proof spoon, an oven, oven mitts, and a timer. The dough should be purchased or prepared ahead of time. It is important to have at least two identical loaves to observe so that one can be cut after the bread begins to appear solid and cooked, and the other can be cut after the bread is clearly solid and browning. When I conducted this experiment at home, I used a rapid rise white bread recipe and a bread machine to make the dough. The bread cooked quickly and tasted delicious. I examined the bread by pushing on it with a heat-proof spoon. I then recorded the appearance and malleability of the bread at five- minute intervals. After 10 minutes, the bread was still malleable from the outside, though it was clearly not able to flow. After 15 minutes, the outside was fairly hard and light brown, yet the inside was very soft and able to change shape with little force. After 20 minutes, the outside crust was dark brown and hard, and the inside was firm and able to resist moderate pressure.

Subjective solids. These pictures show the bread after 15 and 20 minutes.

Before baking, the teacher will ask the students to predict how long it will take to bake the dough and create solid bread. Some of the students may have background knowledge to share with the class in order to help make an educated prediction. Of course, they will also have to agree on what the bread looks like when it has become solid, baked bread, so they will know when to stop the timer and remove the bread from the oven. Once the students have made predictions and written their reasoning in their journals, they will be ready to experiment with baking bread. They will measure and form several equal sized mounds of dough and place them in the oven at the same temperature (after reviewing the need for all variables except time to be the same). The teacher will set the timer and have students check on the dough frequently, at least every five minutes, recording the time elapsed and the appearance of the dough. When the dough has become solid bread, they should remove it from the oven and write about the results of the experiment. Then they may enjoy eating the bread!

*Changing Liquids to an Emulsion: Making Mayonnaise* [22]

Next, the students will use some common liquids to make a gel- mayonnaise. For each team, the teacher will need to gather 2 egg yolks, 3 tablespoons lemon juice, ¼ teaspoon salt, a pinch of pepper and 1 cup of oil, as well as a large bowl and a whisk. He or she will have the students combine all the ingredients except the oil, noticing the fluidity and viscosity of each of these before mixing. Then, the teacher will instruct students to whisk in a few drops of oil at a time until the mixture is smooth. It is really important to mix the oil into the mixture very slowly. After more than half the oil has been added a few drops at a time, students may add the rest of the oil, still slowly, stirring all the while. Finally, when the oil is completely incorporated, students will use a wire whisk to beat the mixture quickly. If this has been done carefully and mixed vigorously for at least five to ten minutes, the liquids will have turned to a thick yellow emulsion: mayonnaise. The students will record their observations in their journals and explain that the egg yolks hold all the liquids together as one thick, smooth suspension that neither holds its shape like a true solid nor flows freely like a true liquid.

Making mayonnaise takes patience, since the oil must be whipped in a little at a time and the mixture must be whisked for a long time before the mayonnaise thickens.

*Changing Solid Particles and Liquid to a Gel: Making Jello Fruit Mold*

Finally, the students will create a gel using solid gelatin particles and water. This activity will take approximately two hours including data collection. First, each group of students must gather a large bowl, a whisk, gelatin fruit mold mix, cold water, a measuring cup, and a cup of boiling water. The students will predict how long the Jello will take to become a gel and record their predictions in their journals. Then, they will combine the gelatin powder and the boiling water. They will stir the mixture thoroughly with a whisk and then whisk the cold water into the mixture. Students will place the mixture in the refrigerator and make observations every ten minutes until the jell-o has formed a gel. When complete, the jell-o holds together and resists flowing, but does not truly retain its own definite shape when dropped. It will be important for students to write descriptively in their journals about each observation, since the changes will be subtle and gradual. This sample data table shows some results the teacher might expect students to observe.

| | |
|---|---|
| 20 min. | totally liquid, freely flowing |
| 30 min. | slightly thicker, freely flowing |
| 50 min | thicker, flows but sticks to sides of the bowl |
| 70 min | flows slowly with more force, jiggles, moves as a whole |
| 80 min | jiggles, same consistency throughout, spreads when dropped |
| 120 min | jiggles, retains same basic shape when dropped |

For an interesting extension, students will be asked to predict what will gel faster when comparing gelatin fruit mold and non-gelatin, vegetarian fruit mold mix made from seaweed. The students will follow the steps of the scientific method to find the results. Please note that non-gelatin fruit mold gels faster than Jello, in about 1 hour, but is slightly less firm than Jello when completely set. Non-gelatin fruit mold mix may be purchased at

health food stores or online.

## Bibliography/ Resources for Teachers


Barham, Peter. The Science of Cooking. Germany: Springer-Verlag Berlin Heidelberg, 2001. This explains the scientific principals that affect cooking in easy to read format.

Bosak, Susan B. Science Is....Canada: Webcom Limited, 1991. This is a large, user-friendly collection of science experiments with short explanations of scientific principles.

Carolina Press. STC Teacher's Guide: Liquids and Solids. Burlington, NC: Carolina Biological Supply Company, 2005. This describes lessons and objectives for sorting activities involving liquids and solids separately.

Chu, Michael, "Homemade Mayonnaise," Cooking for Engineers, http://www.cookingforengineers.com/recipe/43/Homemade-Mayonnaise

This website provides concise and clear directions on how to make mayonnaise.

Doris, Ellen. Doing What Scientists Do. New Hampshire: Heinemann, 1991. This is an excellent resource on teaching science with inquiry, especially for new teachers.

Edinformatics.com, "Suspensions and Colloids," http://www.edinformatics.com/math_science/suspensions_colloids.htm This site has a useful chart showing different types of suspensions.

Heddle, Rebecca. Science in the Kitchen. London, England: Usborne Publishing Ltd, 1992. This has fun kitchen experiments and activities for home or school.

Gega, Peter C. Science in Elementary Education. New Jersey: Prentice Hall, 1990. This is a comprehensive science book with easy to read information on most elementary science concepts and some experiments to go with them.

Hirschfeld, Robert and Nancy White. Kids' Science: Creative Experiences for Hands on Fun. Vermont:Williamson Publishing, 1995. This book is filled with fun experiments designed for children ages 4 to 10 and informational reading geared for older children, parents, or teachers to read to the children.

Jaworski, Stephanie. "Chocolate Sauce Recipe," http://www.joyofbaking.com/ChocolateSauce.html A delicious idea for melted chocolate.

McGee, Harold.On Food and Cooking: The Science and Lore of the Kitchen. New York: Scribner, 2004. This is a very informative, somewhat technical but fairly easy to read book with information about most foods.

National Science Foundation Science and Technology Center for Environmentally Responsible Solvents and Processes (CERSP), "Oobleck," http://www.science-house.org/CO2/activities/polymer/oobleck.html This site gives a recipe for "oobleck" which is called "magic mud" in this unit and explains why it acts the way it does.

Nye, Bill. Bill Nye the Science Guy's Big Blast of Science. Cambridge, Massachusettes: Perseus Books, 1993.This has detailed and easy to read information on the scientific method and many science concepts, including matter.

Penrose, Gordon. 1987. Magic Mud and Other Great Experiments. New York: Simon & Schuster, 1987. This has lots of experiments and science magic tricks.

Science and Engineering Experiments for Kids."Solids, Liquids, Gases." http://www.msm.cam.ac.uk/SeeK/solid.htm This web site offers and excellent introductory lesson.

VanCleave, Janice. Janice VanCleave's 200 Gooey, Slippery, Slimy, Weird and Fun Experiments. New York: John Wiley & Sons, 1993. A book of excellent, fun experiments.

## Children's Classroom Reading Selections/ Resources for Students (and Teachers)

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Bayrock, Fiona. States of Matter: A Question and Answer Book. Mancato, Minnesota: Capstone Press, 2006. This book has excellent questions on states of matter, weather, and other interesting aspects of matter. It has great illustrations, index, glossary, etc. It is appropriate for students reading at high-second grade/ early third grade level .

BBC. "Bitesize" http://www.bbc.co.uk/schools/ks2bitesize/science/materials.shtml

This website provides fun and interactive activities for students on matter, changing states, and a variety of related topics. Quizzes and informative answers are included.

Bodach, Vijaya Khisty. States of Matter. Logan, Iowa: Perfection Learning Corporation, 2006. This has excellent details and examples to help students understand. It also contains a glossary, index, charts and illustrations. It is appropriate for shared reading or independent reading for students reading at high-third or fourth grade level.

Curry, Don L. What Is Matter? Danbury,Connecticut: Children's Press, a division of Scholastic, 2004. This explains states of matter at a first grade level.

Garrett, Ginger. Solids, Liquids and Gases. Danbury,Connecticut: Children's Press, a division of Scholastic, 2004. This explains states of matter at a first grade level.

Gibson, Gary. Science for Fun: Making Things Change. Brookfield, Connecticut: Copper Beech Books, 1995.This has fun experiments for changing states and other changes.

Heddle, Rebecca. Science in the Kitchen. London, England: Usborne Publishing Ltd, 1992. This has fun kitchen experiments and activities for home or school.

Mason, Adrienne. Change It!:Solids, Liquids, Gases, and You . Tonawanda, NY: Kids Can Press, 2006. This has explanations and experiments. It is written for high-first grade level or early second grade level readers. It includes additional information for teachers.

Mason, Adrienne. Touch it! Materials, Matter, and You. Tonawanda, NY: Kids Can Press, 2005. This has explanations and experiments to explore matter and would also be useful for introducing observations and describing. It is written for high-first grade level or early second grade level readers. It includes additional information for teachers.

Nye, Bill. Bill Nye the Science Guy's Big Blast of Science. Cambridge, Massachusettes: Perseus Books, 1993. This has detailed, fun to read information on the scientific method and many science concepts, including matter. It is intended for fifth or sixth grade level.

Ontario Science Centre. Starting With Science: Solids, Liquids, and Gases. Tonawanda, NY: Kids Can Press, 1995. This contains experiments and explanations, index, glossary, and a kid friendly explanation of why the "magic mud" or "oobleck" acts as it does.

Purdue University, "Gases, Liquids, and Solids," http://www.chem.purdue.edu/gchelp/liquids/character.html This web page has a great visual representation of the molecular movement of the 3 states of matter.

Ross, Michael Elsohn. What's the Matter in Mr. Whiskers' Room? Cambridge, MA: Candlewick Press, 2004.This is a fiction book in which the characters learn scientific principles and conduct experiments on matter. It is for second grade reading level.

Tocci, Salvatore. Experiments with Solids, Liquids, and Gases. Children's Press, a division of Scholastic, 2001. This contains narrative explanations of states of matter and experiments, written for second grade level.

Zoehfeld, Kathleen. What is the World Made Of? All About Solids, Liquids, and Gases. HarperCollins Pub. New York: Harper Collins Publishers, 1998. Narrative about liquids and solids for high first grade or early second grade level.

## Appendix 1: Implementing District Standards

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## Grades PreK-2 Core Scientific Inquiry, Literacy and Numeracy

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A INQ.1- Make observations and ask questions about objects, organisms and the environment.

Students will predict, discuss and observe during science experiments and projects.

A INQ.2- Use senses and simple measuring tools to collect data.

Students will observe with the senses and measure with thermometers and measuring tools.

INQ.3 Make predictions based on observed patterns.

For each project, students will make predictions and test their predictions.

A INQ.4- Read, write, listen and speak about observations of the natural world.

Students will work in groups, discuss in class, and write in science journals throughout the unit.

A INQ.5- Seek information in books, magazines and pictures.

Students will complete research with library books, internet use, and pictures.

A INQ.6- Present information in words and drawings.

Students will have to present findings in speeches, drawings, and in writing.

A INQ.7-Use standard tools to measure and describe physical properties such as weight, length and

temperature.

Students will use thermometers, rulers, and measuring tape as part of record keeping and science experiments.

## Grade 2 Content Standards

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Properties of Matter - How does the structure of matter affect the properties and uses of materials? (PHY)

2.1 - Materials can be classified as solid, liquid or gas based on their observable properties.

A18 Describe differences in the physical properties of solids and liquids.

## Appendix 2: Sample Written Response Question Worksheet

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(This sample corresponds to the one of the second grade reading selections, What is the World Made Of? , by Kathleen Weidner Zoehfeld.)

What is the World Made of? Written Response

Focus Question: What important facts did you learn about solids and liquids from this book? Give details from the text to show why these facts are important.

Remember to back up whatever you write in your topic sentence with details from the text that prove your point.

## Appendix 3: Sample Science Observation Journal

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My name is _____Date_____

Observing Solids Journal

1. What did you notice about the solids you observed today?
2. How did you sort your objects?
3. Choose one of the solids you examined today. Draw it and then write all about the properties you observed. Solid:
4. Choose one other solid that was different. Draw it and then write about the properties you observed. Solid:

## Appendix 4

Name_____ Date_____

## Science Experiment Log

What are you hoping to learn more about?
How did you become interested in this topic?
What books or websites have helped you to learn about this topic?
What are some things you already know that will help you understand this experiment?
What is the objective of this experiment? (What do you want to find out?)
What is your hypothesis? (That's your best guess about what will happen.)
What might happen that would prove your hypothesis correct? What do you expect to happen?
What might happen that would prove your hypothesis wrong?
Why do you want to know the results of this experiment?
What materials are you using to help you make your discovery?
What is your procedure for this experiment? (What are the steps?)
What do you observe? (Make a small picture, then write about it.)

## Endnotes

[1] Purdue University, "Gases, Liquids, and Solids," www.chem.purdue.edu
[2] Peter Gega, Science in the Elementary Classroom, 243
[3] Peter Gega, Science in the Elementary Classroom, 243
[4] Peter Gega, Science in the Elementary Classroom, 243
[5] Edinformatics.com, "Suspensions and Colloids" www.edinformatics.com
[6] Edinformatics.com, "Suspensions and Colloids" www.edinformatics.com
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[8] Peter Barham. The Science of Cooking, 144
[9] Edinformatics.com, "Suspensions and Colloids" www.edinformatics.com
[10] Bill Nye. Bill Nye the Science Guy's Big Blast of Science, 1-15
[11] Bill Nye. Bill Nye the Science Guy's Big Blast of Science, 1-15
[12] Robert Hirschfeld and Nancy White. Kids' Science: Creative Experiences for Hands on Fun, 76
[13] Carolina Press. STC Teacher's Guide: Liquids and Solids
[14] Carolina Press. STC Teacher's Guide: Liquids and Solids
[15] Bill Nye. Bill Nye the Science Guy's Big Blast of Science, 1-15
[16] Carolina Press. STC Teacher's Guide: Liquids and Solids
[17] Carolina Press. STC Teacher's Guide: Liquids and Solids
[18] Penrose, Magic Mud and Other Great Experiments, 8-9
[19] National Science Foundation Science and Technology Center for Environmentally Responsible Solvents and Processes (CERSP), "Oobleck," http://www.science-house.org/CO2/activities/polymer/oobleck.html
[20] Stephanie Jaworski. "Chocolate Sauce Recipe," http://www.joyofbaking.com/ChocolateSauce.html
[21] This activity is adapted from Rebecca Heddle. Science in the Kitchen, 8
[22] Michael Chu, "Homemade Mayonnaise," Cooking for Engineers, http://www.cookingforengineers.com/recipe/43/Homemade-Mayonnaise