NEW BEDFORD OCEANARIUM

WOW Mobile Curriculum

The Wonders of Water

Curricular Materials for Understanding The Properties of Water

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Introduction

Regardless of where we live, water is all around us and is necessary for our survival. It's in the food we eat and in the plants and trees in our environments. We drink water, wash and cook with it, transport cargo and people on water, and use it for recreation. Interestingly, fresh and saltwater together support more plant and animal life than the land-so we also depend on water for sustenance.

While water is vital to our existence, we sometimes take it for granted. We know that we get some water from rain and snow. We see that some things float in water and others sink. If we live in cold climates, we are aware that in the winter, water freezes. Why? Scientists study water. They pose hypotheses, plan and conduct experiments, and thereby provide explanations that help us understand the various phenomena that we observe about water. These explanations are often complex and difficult to teach our students. You will find background information about water in the "Notes to Teachers" section that follows this introduction

This module contains a series of hands-on activities designed to help teachers and students understand the properties of water. The activities can be used to introduce, reinforce, or re-teach concepts about the properties of water. Teachers can use these activities as part of curricula on:

- Density;
- Buoyancy;
- Salinity:
- Surface tension;
- Mass, weight, and volume;
- Thermohaline circulation (the circulation of the oceans); and
- The therrmocline (a layer within a body of water where the temperature changes rapidly with depth).

These activities provide students with hands-on opportunities to:

- Investigate surface tension;
- observe, predict and test the buoyancy of an object;
- explore the relationship between salinity and density;
- investigate the relationship between temperature and density; and
- describe the physical characteristics of water.

Notes to Teachers

Water covers over 70% of the earth's surface. Water is so common and abundant that we often take it for granted and don't realize that water is one of the most unusual and unique substances in the solar system and possibly in the entire universe.

What are the physical properties that make water so unique? To understand these special properties, it is first necessary to understand the chemical structure of the water molecule. Water is a very simple molecule made of two atoms of Hydrogen and one atom of Oxygen. Hydrogen and Oxygen are two of the lightest atoms on the Periodic Table of Elements. When these atoms chemically combine to form water, unusual properties occur. A molecule of water is formed when two atoms of Hydrogen, which is highly explosive and the very lightest of all elements, combine with one very light and very reactive Oxygen atom. The single electrons from each Hydrogen atom form a bond with electrons from the Oxygen atom to complete the outer electron orbits for each atom to produce the new water molecule. The electron pairs are closer to the Oxygen molecule. This produces a negatively charged pole (-) at the Oxygen end. The Hydrogen atoms at the other end of the water molecule carry a positive charge (+). The result is a highly charged *bi-polar* molecule of water.

Each bi-polar water molecule now acts like a magnet to attract or repel other charged polar substances. The opposite charged ends of each molecule attract opposite charged poles from other molecules to form weak bonds called Hydrogen Bonds. All these molecules will stick to each other like a pile of magnets. When water molecules stick to each other, this is called *cohesion*. The property of cohesion enables water to be pushed and pulled in a variety of ways, similar to magnets. When this cohesion of water molecules happens at the surface of the water, it is called *surface tension*. The cohesion force between water molecules may be strong enough to keep objects that may be denser than the water (e.g. pins, paper clips, many bugs, and the like) from breaking the surface tension of the water and thus, the objects sit on the surface of water as if it were a trampoline.

Because water is such a strongly charged polar molecule, the positive (+) and negative (-) polar ends of water molecules attract many other electrically charged molecules to form new Hydrogen Bonds. The new Hydrogen Bonds keep these substances uniformly mixed with the water molecules. This mixture is called a *solution*. Many types of salts are charged polar molecules and will readily dissolve in water to form a solution. That is why water is called the universal solvent. Each and every drop of open ocean seawater is a highly charged ionic soup with each drop containing over 60 elements from the Periodic Table. This unique property of water is also why water is so important to all living things on

earth. Every nutrient, enzyme, and other chemicals necessary for life processes are all able to dissolve in water, where life-supporting chemical reactions occur. Water is also the means by which chemicals are transported throughout the organism.

Water is also unique in that its solid form, ice, is less dense than its liquid form. Ordinarily, in a water molecule, the angle that holds the two hydrogen atoms to the oxygen atom is 105 degrees. When water freezes, the angle expands to 109 degrees. This increase of separation of 4 degrees between each Hydrogen molecule as the water freezes and changes from the liquid phase to the solid phase increases the amount of space each water molecule takes up. In addition, the lower temperature slows molecular motion in the liquid water. As water turns to a solid, many new multiple Hydrogen Bonds develop between the Hydrogen atoms to fix the ice in a crystalline matrix. This further slows the motion of molecules and reduces the fluid nature of liquid water. The result is an increase in the space the ice takes up. The ice volume increases but the mass remains the same. This change makes the expanded ice molecules less dense than the same number of water molecules, so the ice floats. The expansion of each freezing water molecule by 4 degrees and the formation of many new Hydrogen Bonds as it expands into the crystalline state of ice, produces a very powerful force. Expanding ice molecules can crack metal water pipes, rupture automobile engine blocks, split rocks in half, and change the face of mountains and continents. It was the force caused by the formation of ice that broke the face off the "Old Man in the Mountain," New Hampshire's state symbol, in the White Mountains of the Northeast.

Water, which we may take for granted, is in fact an extraordinary substance. Every time we add ice to a glass of water and watch the ice float, it is a scientific marvel. If water were not unique and ice didn't float, then conditions on our planet Earth would be greatly altered. If the ice on the earth sank deep into the *aphotic abyss*, the portions of oceans and lakes that are not exposed to sunlight, these bodies of water would freeze from the bottom up and the earth would be completely changed.

The distinctive physical properties of water help control and maintain the living environments on Earth. The waters of our global oceans contain most of the world's living cells and organisms. Specifically, the oceans contain over 97 percent of the earth's water molecules and numerous other dissolved chemicals in a kind of an earth soup.

Water has a high capacity to absorb and hold heat. In fact water has a greater ability to store heat and can dissolve more other substances in greater amounts than any other liquid known. When ice melts, the weak Hydrogen bonds break apart due to increased motion and vibration of the moving molecules. As the crystalline matrix breaks up, many of the Hydrogen Bonds break and water molecules move more freely in the liquid state with fewer bonds to slow the

molecules. If the water continues to heat, the molecules vibrate and move even faster until all Hydrogen Bonds break apart and the water molecules separate from each other. This state, when water molecules move freely about, is called *water vapor*. Water is in its gaseous phase.

The physical changes that water undergoes, from solid to liquid to gas, happen each and every day as part of the Water Cycle here on earth. Also, the heating and cooling of water plays a critical role in maintaining the earth's climate, weather and annual temperature patterns.

All living things are linked to the sustaining abilities of water. Because of its unique properties, water makes the earth livable.

For additional information see: http://www.hbci.com/~wenonah/hydro/h2o.htm and http://ga.water.usgs.gov/edu/waterproperties.html.

Activity One

Surface Tension and the Water Molecule

Overview

The students will explore the structure of water molecules and test the surface tension of water by attempting to float a paper clip.

Introduction

This activity assumes that students understand the following:

- Water appears in three states: solid, liquid, or gas.
- A water molecule is the smallest unit of water; each water molecule consists of two hydrogen atoms and one oxygen atom.
- Water molecules are attracted to each other. The oxygen end of water has a negative charge and the hydrogen end has a positive charge. The hydrogen of one water molecule is attracted to the oxygen of other water molecules. This is called cohesion.

Objective:

Students will understand that surface tension is the result of the attraction between the water molecules at the surface of the water (cohesion). Surface tension makes it possible for water to hold up a pin or paper clip, even though both are heavier than the water. For a further explanation see: http://www.uni.edu/~iowawet/H2OProperties.html.

Materials

- Paper clips
- Water
- Plastic cups

Activity: Surface Tension

- Place students in pairs. Give each pair of students a plastic cup that is half full of water and several paper clips.
- Predicting: Ask students to discuss and predict what will happen when a paper clip is dropped into the cup of water. Ask students to offer explanations for their predictions.
- Direct students to drop a paper clip in the water.
- Was your prediction accurate? Did your paper clip float or sink? Why do you think this happened?
- Students remain in pairs. Their assignment is to work together to design a method for placing the paper clip on the water so it doesn't sink.
- Students should try to float as many paper clips as possible in five minutes.
- Writing to Learn: Ask students to answer the following questions:
    - Normally your paper clip would sink; what do you think is causing it to float?
    - How many paper clips were you able to float in five minutes?
- Bring the class together and ask students to guess why the paper clips didn't sink.
- Accept all guesses, as this is a way to assess students' knowledge.
- If you have computers available, show students the information about surface tension at: http://www.uni.edu/~iowawet/H2OProperties.html.
- Discuss and explain surface tension. Ask students to describe ways they have seen plants and animals take advantage of this unique property of water. For example, 1) there are insects that can walk on the surface of water; 2) there are plants that float on the surface of water where the leaves are exposed to sunlight which the plants need to produce their own food through the process of photosynthesis; 3) frogs take advantage of floating leaves as a strategic location for catching insects, and the like.
- Writing to learn: Ask individual students to complete the following in their journals:
    - Draw and label a water molecule.
    - Explain cohesion.
    - Explain surface tension.
    - Give an example of how surface tension helps support some forms of life on earth.
- Place students in pairs and direct them to read their responses to the partner. Ask students to compare and contrast their responses and identify disagreements. The teacher will circulate and clarify.
- Ask each pair of students to find another pair of students and create a group of four. Again, each individual student will read his or her responses and students will identify disagreements. The teacher circulates and checks for understanding.
- The teacher will collect all journals to assess student learning and identify students who require additional instruction.

Learning Experience Two

What Floats and what Sinks?

Overview

In this activity, students in the early elementary grades begin to use scientific inquiry to explore “what floats and what sinks.” They are provided with a variety of objects. Students examine the objects, predict whether they will float or sink in water, and explain their predictions.

Introduction

This activity assumes that students are unfamiliar with the concept of density. The activity can serve as an introduction to density or as a tool for providing a concrete experience for students who benefit from hands-on learning.

Objective

Students will identify factors such as weight, shape, and size that determine whether an object floats or sinks.

Materials

- Objects that will float in water (8-10 per group)
- Objects that will sink in water (8-10 per group)
- A clear plastic container for each group
- Water
- Food coloring or non-toxic paint

Activity

- Place students in groups of 4
- Provide each group with 8 -10 objects that will float and 8 – 10 objects that will sink.
- Select a student in each group to act as Recorder, writing down predictions and results.
- Distribute one copy of Handout One to each group.
- Ask the groups to examine each object and predict whether it will float or sink in water. Their predictions can be recorded on Handout One.

- When students have completed their predictions, provide them with a clear plastic container filled with water. Ask students to test their predictions and record their results.

Learning Experience Two

Handout One: Float or Sink?

What is the object?	Sink or Float?	Why do you make that prediction?	Was your prediction right? Why or why not?

Learning Experience Three

Overview

In this activity, students explore the relationship between variations in temperature and density.

Introduction

This activity is for older elementary students. The activity can serve as an introduction to water molecules and how they are affected by temperature.

Objective

Students will explain how temperature affects water molecules.

Materials

- A two chambered beta container
- Colored warm water and different colored cold water
- Ice cubes

Activity

- Using a two-chambered container, fill one side with cold water and other with warm **colored** water.
- Check for understanding: Do students understand that water is made up of molecules?
- Explain to students:
    - All water-both warm and cold-contains molecules. However, the molecules in warm and cold water act differently.
    - The molecules in warm water move around quickly and bounce off each other. The faster the molecules move and bounce off each other, the greater the space between them.
    - Molecules in cold water move less quickly and bounce off each other less. Thus, there is less space between them.
    - As a result, the same volume of cold water is more densely packed with molecules and weighs more than warm water.
- Tell students that you're going to remove the center divider. Be careful not to stir or disturb the water, as this will interfere with the experiment.
- Ask students to predict (in their journals) what they think will happen to the water when you remove the divider. Ask them to explain their predictions.
- Remove the center divider. Again, ask students to write in their journals: What happened to the warm and cold water? They should describe their

observations and explain why they think this happened (warm, colored water rises because it is less dense and weighs less than the cold water.)

- Place students in groups of four. Ask them to discuss their explanations.
- Process with the class and identify their conclusions about which is more dense and why.
    - Ask students to predict what they think might happen if you add ice, which is colder, to the mix. They will probably predict that the ice will float, based on their own experience.
    - Ask students why they think the ice will float. Record their responses on the board or chart paper.
- Provide each group with ice cubes. Have students place the ice cubes in their water bucket and draw what they observe.
- Explain to students:
    - "When water freezes and changes into a solid (ice cubes), its molecules arrange themselves so that they occupy more space. Another way to think about it is that a quart of ice weighs less than a quart of water. The ice is lighter, so it floats. (Most liquid substances contract and occupy less space when they change to their solid forms:
    - You can find additional information at the following website: http://www.highlightskids.com/Science/ScienceQuestions/h1sciQicecubesFloat.asp

- Process: Summarizing and Reflecting:
- Ask students to spend ten minutes writing you a letter about:
    - Something they learned,
    - Something they don't understand or need help with,
    - How what they've learned can apply to their lives:
        - Car radiator and antifreeze
        - Pipes freezing in the winter
        - When you go swimming, where is the water warmer or colder?
        - All divers wear insulated suits when they dive deeply into the ocean and lakes.

Learning Experience Four

Salinity

Overview

Students explore the relationship between salinity and density.

Objective

Students will explain how salinity and gravity are related to the density of water.

Materials

- Salt
- Food coloring or non-toxic, water color paints
- Tall clear straws, set of four for each group
- Set of four tall plastic cups or containers that hold a minimum of eight ounces for each group

Activity

- Students will work in groups of five. Ask students to count off in their groups (one to five). Students one, two, three, and four will do the experiment; student five will gather the data and serve as the recorder.
- Before class, prepare a set of materials for each group plus one extra set. Each set will consist of four tall clear plastic drinking straws and four tall plastic cups. Each cup should be at least ¾ full. Use water, salt, and food coloring (or water color paints) to create the solutions. Label the cups accordingly:
    - Tall cup A: Plain water (red)
    - Tall cup B: Water containing one teaspoon of salt (green)
    - Tall cup C: Water containing three teaspoons of salt (blue)
    - Tall cup D: Water containing six teaspoons of salt (yellow)
- Distribute the materials to each group.
- Assign each student to a different sequence of colors.
    - Student One: A, B, C, D
    - Student Two: D, C, B, A
    - Student Three: B, A, C, D
    - Student Four: C, D, A, B,
- Practice: Have students practice immersing the straws ½ inch into the different cups and placing a finger over the top of the straw. Hold the finger on the top to close the sample without losing it and lift it out of the cup. Move to the next cup without dropping the first sample and add ½

inch sample from the second cup. Repeat this procedure, collecting ½ inch samples from each cup in the straw until students master this phase.

- Then ask students in the groups to immerse their straws ½ inch into the first assigned colored solution, placing a finger over the top of the straw to seal the top. Direct students to lift the straw out of the solution with the finger holding the top closed. A sample of the solution will be in the straw.
- Next, students place the straw containing the liquid into the second solution, release the finger from the top, and add ½ inch of the second solution to the straw. Lift the straw out of the solution holding the top closed and the two samples in the straw.
- Repeat this process until ½ inch samples of all four solutions are in the straw.
- Ask students to observe each straw in order and describe what they see. The recorder takes notes, as students discuss their findings.
- It may be helpful to have students hold a finger at the bottom of the straw at this time to keep the final sample intact. Then have another student hold a piece of white paper as background behind the straw to help students observe any fine contrasts in color layers or any other unusual observations that occur inside the straws. You may wish to plug the bottom of the straw with clay or play dough to make a more permanent seal; the clay may also be used to make a base, holding the straw in an upright position while students observe various results. You may also cap off the tops and leave the straws aside so students can observe straws over several days and note any changes.
- Prompts for students:
    - What happened to the different solutions in the four straws? (They should observe that in three of the four, the colors mixed either completely or partially. The colors in the fourth should remain in the order in which they were collected.)
    - Ask them to guess what happened and why?

- Explanation/Discussion: There are two concepts that you will need to explain to students at this point, gravity and density.
    - The earth's gravity is a force that pulls all materials toward the center of the earth. See http://www.glenbrook.k12.il.us/gbssci/phys/CLass/circles/u6l3a.html
    - Density: The more molecules in a material, the denser the material and the stronger the pull of gravity on that material. Therefore, most dense materials will be pulled down to the bottom of all fluids with a stronger force than less dense materials. http://www.mcps.k12.md.us/departments/eventscience/Baseball/EBS.crp2df2.html
    - Discuss and Process: Any combination of water and salt is denser than just water. The more salt, the denser the water.

- Summarize and Process: Use a large graduated cylinder (100, 500, or 1000 cc's) and the extra set of cups you prepared (above). Slowly and carefully add each of the solutions, in order, from the densest to the least dense (D, C, B, A). Ask students to observe and explain what they see in their journals using the following prompts:
    - Compare the results they obtained using the straws with those obtained through the class display.
    - What do they observe?
    - Are the results the same or different?
    - Why?

- Cover the cylinder with plastic wrap and place it in a shady place in the room.
    - Revisit the display throughout the year and relate to density layering in the oceans.

Learning Experience Five

Salinity and Temperature

Overview

Students are working with two variables now: temperature and salinity. The objective is for students to determine which of the two has a more significant impact on the density of the water.

Objective

Students will explain the relationship between gravity, temperature, and density.

Materials

- Warm and cold water
- Salt
- Food coloring or non-toxic, water color paints
- Tall clear straws, set of four for each group
- Set of four tall plastic cups of containers that hold a minimum of eight ounces for each group

Activity

- Students will work in groups of five. Students will count off in their groups (one to five). Students one, two, three, and four will do the experiment; student five will gather the data and serve as the Recorder.
- In advance, prepare a set of materials for each group plus one extra set for you. Each set will consist of four tall clear plastic drinking straws and four tall plastic cups. Each cup should be at least ¾ full. Use water, salt, and food coloring (or water color paints) to create the solutions. Label the containers with the letter and specific contents.
    - Sample A: The first should be warm fresh water (blue).
    - Sample B: The second should be cold fresh water (green).
    - Sample C: The third should be warm water mixed with six teaspoons of salt (yellow).
    - Sample D: The fourth should be cold water mixed with six teaspoons of salt (red).

- The next step is for students to use a clear drinking straw to determine the comparative density of the four solutions - from least to most dense.
- Students will collect a ½ inch sample of water from each cup in the following order:

    - Student One will begin with Sample A then move in order to Samples B, C, and D.
    - Student Two will begin with Sample B and end with Sample A (B,C,D,A)
    - Student Three will begin with Sample C and end with Sample B (C,D,A,B)
    - Student Four will go in REVERSE order beginning with Sample D (D, C, B, A).

Have students practice immersing the straws ½ inch into the different cups and placing a finger over the top of the straw. Hold the finger on the top to close the sample without losing it and lift it out of the cup. Move to the next cup without dropping the sample and add ½ inch sample from the second cup. Repeat procedure, collecting ½ inch samples from each cup in the straw, until students master this phase

- Then ask students in the groups to immerse their straws ½ inch into the first assigned colored solution, placing a finger over the top of the straw to seal the top. Direct students to lift the straw out of the solution with the finger holding the top closed. A sample of the solution will be in the straw.
- Next, students place the straw containing the liquid into the second solution, release the finger from the top, and add ½ inch of the second solution to the straw. Lift the straw out of the solution holding the top closed and the two samples in the straw.
- Repeat this process until ½ inch samples of all four solutions are in the straw.

It may be helpful to have students hold a finger at the bottom of the straw at this time to keep the final sample intact. Then have another student hold a piece of white paper as background behind the straw to help students observe any fine contrasts in color layers or any other unusual observations that occur inside the straws. You may wish to plug the bottom of the straw with clay or play dough to make a more permanent seal; the clay may also be used to make a base, holding the straw in an upright position while the students observe various results. You may also cap off the tops and leave the straws aside so students can observe straws over several days and note any changes.

- Ask students to observe each straw and discuss their findings. The Recorder takes notes:
    - What did students observe?
    - What happened to the different solutions in the four straws? (They should observe that in three of the four, the colors mixed either completely or partially. The colors in the fourth should remain in the order in which they were collected.)
    - Ask them to guess what happened and why?

    - Explanation/Discussion: Students are working with two variables now: temperature and salinity. The objective is for students to determine which of the two has a more significant impact on the water column in the straw (the density).

- Gravity and density are responsible for the outcome (see above):
    - In LE Two, students learned that warm water is less dense than cold water.
    - In LE Four, students learned that fresh water is less dense than salt water.
    - They should be able to combine their learning and predict that warm fresh water will be the least dense and cold salt water will be the densest.
    - As for the other two samples, the salty water should be more dense than fresh water and will usually sink below any fresh water. See if that is the case?

Extension: Students can investigate how their learning applies to our understanding of density layers in the ocean and large lakes:

- Stratification
- Upwellings in oceans and large lakes
- Fall and spring turnover
- Plankton blooms