Connecting Oceans Academy

New Bedford ECHO Project

The Mysteries of Water II: an Interdisciplinary Investigation for Grades 7-9

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The Mysteries of Water II: an Interdisciplinary Investigation for Grades 7-9

Overview

Consider that water is everywhere on planet Earth: two-thirds of the planet is covered with water, our bodies are fifty to 75% water. In short, life cannot exist on earth without the existence of water.

Now, consider the fact that water in its solid form actually floats on top of liquid water. Other substances in their solid state would sink when placed into the liquid form of that substance. This anomaly of water is one consequence of water's unique chemical structure, which results in frozen water being less dense than the liquid form. Because solid water (ice) floats, organisms that live in lakes are able to survive winters in cold climates. Water is a naturally occurring molecule that exists in all three states of matter on our planet—solid, liquid and gas. It can also be a powerful force of nature over which humans have no control.

Beyond its essential role in sustaining life, water has had both a positive and negative impact on humankind throughout its existence, determining where societies are established, as an object of greed and a motive for murder, an uncontrollable agent of devastation, and a symbol for spiritual renewal, just to name a few examples.

Even though water is pervasive on this planet, the negative impact of human activity on both the quality and quantity of water looms as one of this century's most critical challenges. Water conservation and the prevention of water pollution are the responsibility of every person. Each person can mitigate his or her negative impacts on the fresh water supply through thoughtful action and informed decisions.

Content

This module is cross-disciplinary in its design allowing for a range of collaborative teaching possibilities. It can be taught by a cross-disciplinary team or teachers can select Learning Experiences (LEs) that address the objectives within their respective disciplines. The module also emphasizes a student-centered, inquiry approach to teaching. Part I falls within the discipline of science, and introduces or reinforces what students already know about the unique properties of water, including how the chemical structure of the molecule gives water its unique physical properties, and how these properties make life possible on Earth. In Part II, students explore the impact of water throughout human history—physically, socio-economically, politically, and spiritually. In Part III, students investigate the environmental issues related to water conservation and water pollution, learning how to be, and hopefully making a commitment to be a responsible steward of water.

Pre-testing of Science Explorations

All the inquiries and experiments in this module have been trial tested. However, it is important for teachers to trial test prior to using in the classroom to become familiar with the equipment and procedures.

Equipment and Supplies for Part I: Physical and Chemical Properties of Water

The authors designed activities that use the least expensive, readily obtainable equipment and supplies. A list follows.

Learning Experience 2	-Modeling clay in 2 colors -Toothpicks, 2/student -Protractors, 1 or more per group of 4-6 students -2-3 reference books with diagrams of water molecules -Optional: Access to the Internet -Small index cards or post-its in 2 colors (1/3 of students require a card in one color, 2/3 of students require a card in the other color0 -Bar magnets, 1 per student
Learning Experience 3 Activity 1 Part A	For each group: -Small clear plastic cup -Salt -Measuring spoon (1/4 tsp) -Measuring cup or graduated cylinder -Thermometer -Cup or bowl of ice (large enough to set small plastic cup in) For the class: -Supply of water at room temperature, ice water, and hot water (recommend slow cooker filled with water, ladle) -A means for disposing of salt water (sink, large pot or bowl) -Paper towels
Learning Experience 3 Activity 1 Part B	For each group: -Eight pieces of thin wire cut to 3"(7.6 cm) per group of 4-5 students, contained in an envelope (used also in Activity Three) -Five plain wooden toothpicks which have been colored on one end with a marker -One 4x6 index card or ¼ sheet of 8.5x11" paper per group -One protractor per group (ideally, one protractor per person) -Clay model of water molecule (from Learning Experience Two) -Large chart paper and markers
Learning Experience 3 Activity 2	-Three hot plates -Three cooking pots of same size and shape -Three Pyrex beakers of same size or 1-cup Pyrex measuring cups that will fit easily within the pots (these are the test containers and should be identical in size and shape) -Three thermometers—either scientific or cooking thermometers that can be used to measure temperature from 0^oC (32^oF) to 100^oC (212^oF); again, it is best that they are the same -Isopropyl alcohol (pure alcohol gives best results, but rubbing alcohol can be used with less dramatic results) -Water (sufficient for simmering water baths, optionally ice-water baths, and about 8 ounces for testing) -Optional extension of experiment: Three containers of ice water

	(plenty of ice) large enough for the Pyrex beakers or measuring cups to fit inside (of equal size) -Plastic wrap and rubber band to cover one of the beakers or measuring cups -Three timers to measure a total of 10 minutes and be able to easily track the time elapsed at one-minute intervals -Large chart paper with graphing lines, 3 different colored markers
Learning Experience 3 Activity 3 Part A	For each pair or small group -Penny -Cup partially filled with water -Cup partially filled with alcohol -Eye dropper or pipette -Paper towels
Learning Experience 3 Activity 3 Part B	For each group of 3-5 students -Plastic drinking straw -Glass tubing of varying bore diameters, including capillary tubing -Small container of water with food coloring added -Clear cup or beaker -Rulers to measure millimeters

Backward Design and Scientific Inquiry

Backward Design

This curriculum module is based on the Understanding by Design model of curriculum development by Jay McTighe and Grant Wiggins**.** The learning experiences have been developed to support students' understanding of complex concepts related to the study of water by integrating a study of water from the perspectives of science, sociology, economics, history, geography, arts, religion and spirituality. The sequence of activities is designed to lead students to the enduring understanding that human beings seek to make sense of their environments and want to understand why and how things are as they are. Some have used narrative to understand. Others have turned to science to make sense of complex phenomena. This curriculum focuses on making connections among the disciplines so that students understand why and how water is both essential for life to exist on Earth and an integral component of human activity. The processes of scientific inquiry are used as a means of making sense of not only scientific, but also social phenomena.

Scientific Inquiry

Scientific inquiry refers to "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (National Science Education Standards (NSES), National Research Council, 1995, p. 23). Scientific inquiry reflects how scientists come to understand the natural world, and it is at the heart of how students should learn. From a very early age, children interact with their environments, ask questions, and seek ways to answer those questions. Understanding science content is significantly enhanced when ideas are anchored to inquiry experiences. In the process of learning the strategies of scientific inquiry, students learn to conduct investigations and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions (NSES).

Prerequisite Science Knowledge

The National Science Education Standards assert that even though middle grades students usually have been introduced to vocabulary related to the particulate nature of matter, few students are able to understand the abstract concept of atomic and molecular particles. However, the middle grades science standards (and sometimes at even earlier grades) of many states expect students to know the terms element, atom, molecule and compound. This module incorporates terminology of atoms and molecules, using concrete learning experiences and simulations to introduce students to the unique properties of the water molecule. Through the learning experiences, students acquire an operational understanding sufficient for them to recognize the special properties of water that are so essential to living systems.

This module assumes that students have been introduced to, and have a familiarity with the following terms:

- Matter: any substance that takes up space and has mass. All matter is made of up various combinations of about 100 different elements. Hydrogen and oxygen are examples of elements.
- Elements: combine in a multitude of ways to produce compounds that make up all of the living and nonliving things that we encounter. Hydrogen and oxygen combine to form water.
- Atom: the smallest unit of an element that maintains the characteristics of that element.
- Molecule: the smallest unit of a compound that maintains the characteristics of that compound. Water is an example of a molecule.
- Mass: the *amount* of matter that makes up an object.
- Weight: the measure of the heaviness of a given mass of a substance. Gravity is the force that determines weight. On earth, we can usually use the terms mass and weight interchangeably.
- Volume: the measure of how much space a given quantity of matter takes up.
- Density: the amount of molecules packed into a specific volume of space.
- Magnetism: Magnets have poles that repel and attract each other.

Prerequisite Science Skills

- Measure the volume of liquids
- Measure temperature
- Plot a line graph from a data table
- Use a protractor to measure an angle
- Measure length in millimeters

Resource for Learning Experience (LE) 3: Exploring Physical Properties of Water

The activities build in part on concepts that were acquired in LE One. However, the activities also assume prior scientific knowledge usually acquired in earlier grades. There is a companion module designed to be taught at the upper elementary level, *Investigating the Mysteries of Water I*. If students do not already possess the prerequisite concepts listed below, the teacher may use or adapt Learning Experiences from the elementary module as necessary. For each activity listed in the chart below, the related LEs are provided from the elementary module. It is necessary to assess students' prior knowledge of the prerequisite concepts before beginning each activity in LE 3.

LE 3 Activities	Elementary LE	Prerequisite Concepts
Activity One: Why is Water Called a Universal Solvent?	LE #4	-Molecules are generally in motion—they vibrate. -The greater the heat, the faster the vibration. -As molecules vibrate faster, the distance between the molecules increases.
Activity Two: How Much Heat Can Liquid Water Absorb Before It Changes to a Gas?	LE #2	-Molecules are generally in motion—they vibrate. -The greater the heat, the faster the vibration. -As molecules vibrate faster, the distance between the molecules increases. -For almost all matter, the solid state of a substance is denser than the liquid state, and the gaseous state is the least dense. Water is an exception.
Activity Three: Why Does Water Exhibit the Properties of Cohesion and Adhesion?	LE #3	Water exhibits the property of cohesion because water molecules tend to stick to each other.
Activity Four: Why Does Ice Float on Liquid Water?	LE #2	-Water in solid state is less dense than in liquid state. Water is the only known substance in which the solid state is less dense than the liquid state. -Density refers to the amount of a substance in a given amount of space. The more dense, the greater the amount of substance.

<table>
<tr><th colspan="2">Stage 1–Desired Results</th></tr>
<tr><td colspan="2">Massachusetts Curriculum Frameworks

Science and Technology : Grades 6-8
Physical Science:

• Differentiate between an atom (the smallest unit of an element that maintains the characteristics of that element) and a molecule (the smallest unit of a compound that maintains the characteristics of that compound).
• Give basic examples of elements and compounds.
• Differentiate between mixtures and pure substances.
• Differentiate between physical changes and chemical changes.
• Explain the effect of heat on particle motion through a description of what happens to particles during a change in phase.</td></tr>
<tr><td><u>Enduring Understandings</u>

Students understand that:
1. Without the unique properties of water, it is unlikely that any life would exist on this planet.

2. Water influences and impacts human activity in crucial ways, physically, economically, socially, politically and spiritually.

3. Humans must responsibly manage water resources for the survival of life on earth.</td><td><u>Essential Questions</u>

a. What makes water unique?

b. What is the relationship between the unique properties of water and life on earth?

c. What is an individual’s responsibility to the local and global water resource?</td></tr>
</table>

Content: Students will be able to	**Skills: Students will**
• Draw or build and label a model that represents a water molecule, showing it is composed of one atom of oxygen and two atoms of hydrogen, arranged in a v-shape. • Give examples that show how the polarity of water and the shape of the water molecule account for many of its unique properties. • Describe at least six properties of water, including: - It exists in three forms on this planet: liquid, solid, gas; - In it's solid state, ice, water is lighter (less dense) than in the liquid state and thus ice floats on top of liquid water; - It's colorless, tasteless, odorless; - It dissolves nearly everything; - It can absorb a large amount of heat; - Water molecules stick together (cohesion), forming surface tension and water droplets. ▪ For at least three properties of water, explain why each of these properties is important to living things. ▪ Describe at least five examples of water influencing or affecting human activity. • Explain why water has an unusually large capacity to absorb heat, and cite this property as the reason water plays a key role in moderating climate and weather on earth. • Defend with facts the statement, 'Without water, there could be no life on this planet.' • Describe at least five ways that human activity diminishes the quality and quantity of available water throughout the world.	▪ Plan and conduct a controlled experiment ▪ Collect data from historical, descriptive and experimental research ▪ Interpret data, draw conclusions ▪ Apply scientific knowledge to real world situations ▪ Accurately measure volume of a liquid ▪ Accurately measure temperature ▪ Plot a line graph ▪ Plot a bar graph

Stage 2–Assessment Evidence

Performance Tasks (Students may work alone or in small groups, but each student is responsible for demonstrating the requisite content knowledge and science skills listed above.)

a. Show through drawings, physical modeling, a skit, dance or other

appropriate simulation, the chemical structure of water and at least 5 properties of water.
b. Design and conduct an experiment that explores a property of water.
c. Conduct research and present the findings on a question related to a way that water has a significant impact on humans.
d. Determine the extent to which the local community is aware of water conservation and quality.
e. Plan and carry out at least one initiative to improve public awareness and conservation of water quality and quantity.

Other evidence

- Logs of class experiments and other scientific inquiries
- Teacher-made tests of content knowledge and ability to apply knowledge
- Participation in class activities

Student Self-Assessment: How will students reflect upon and assess their own learning?

- Reflective writing about class activities and student's performance assessments
- Discussion with peers

Stage 3–Learning Plan

Part I: Physical and Chemical Properties of Water
Learning Experiences
LE 1: What Do You Know about Water?
LE 2: Chemical Properties of the Amazing Water Molecule
LE 3: Exploring Physical Properties of Water

Part II: Impact of Water on Human Activity
LE 4: What Do You Know About the Impact that Water Has on Human Activity?
LE 5: Investigating the Ways Water Impacts Human Activity

Part III: Impact of Human Activity on Water
LE 6: What is the Impact of Humans on Water? Investigating Water Use and Water Quality
LE 7: Up Close and Personal: How Do Each of Us Contribute to the Solution or the Problem? How Can We Each Make a Difference?

Part I: Physical and Chemical Properties of Water

Learning Experience One

What Do You Know about Water?

Overview

Guiding Questions: Why would I want to study water? What do I already know about water?

There are two purposes to this learning experience: 1) to pique students' interest in an extensive inquiry into the scientific nature of water, the impact of water on human activity, and the impact of human activity on water; and 2) for the teacher to determine the extent of students' scientific knowledge about the properties of water. Students work individually to prepare as precise a description of water as possible, imagining they are each explaining this phenomenon to a being from another planet who has never heard of water. Students then work in groups to create a description. The groups' descriptions are posted. A visitor, who doesn't know the purpose of the activity, is invited to the class to read the descriptions and tell the class what substance is being described. Students critique their descriptions. Students then engage in a jigsaw activity that highlights how essential and unique water is to the planet Earth.

Evaluation

Students submit their original descriptions of water and write a paragraph explaining why it's important for them to study water.

Materials

- Handout One: Photograph of The Blue Planet*
- Handout Two: Water—We Couldn't Exist Without It! cut into 5 sections
- Chart paper for each group of 4-5 students, and teacher
- Markers
- Masking tape

Activity One: How Would You Describe Water to a 'Being' from Another Galaxy?

Preparation

1. *Option for Handout One: Instead of making copies for each students, you may choose to download the image from http://nssdc.gsfc.nasa.gov/imgcat/hires/a17_h_148_22725.gif for digital projection.

2. Arrange for a person to visit class for about 10 minutes (refer to "Notes to Teachers' at end of LE for instructions)

- Have photograph, "The Blue Planet, Milky Way Galaxy" either ready for distribution as handout or for projection.
- Ask the students to think about how they would describe water to someone who didn't know anything about it? Invite students to imagine they are astronauts and have just landed on a planet in a far away galaxy. Create this scenario:

> *You find you can communicate with a highly evolved species through your thoughts. This otherworldly species has heard of our planet. They have seen Earth through their technologically sophisticated telescopes. They show you a photograph and they ask you, "Why does Earth, unlike any other planet they have observed, appear blue*?" **[Show students photograph, The Blue Planet.]** *You explain through your thoughts that the blue is caused by the reflection of the sun off the water which covers about 70% of our planet. They are baffled. They have no knowledge of the word water. You are asked what 'water' is. Now you must describe water to someone who has had absolutely no experience with it.*

- Ask each student to prepare a description of water that would offer as good an idea of what water is as possible. Allow about 5 minutes, checking work and asking questions to encourage thoroughness, without providing information. Instruct the students not to write the word water anywhere in their description.
- Place students in groups of 4-5. Supply chart paper and markers. Students combine their descriptions to prepare the most complete description they can. Allow them to add new descriptors. Inform students that you have invited a visitor to read their descriptions and try to determine what substance they have described. The only information the visitor will have is that each group is describing a substance that exists on earth.
- When all groups have completed their descriptions, students post the charts on the wall.
- Ask the visitor to enter. The visitor reads all the charts and tries to guess the substance. Allow the visitor to ask only clarifying questions. No hints are allowed.
- Ask the students reflective questions, guided by their work and experience with the visitor.
  - Why do you think the visitor readily determined that you were describing water? Alternatively, why do you think the visitor needed to ask ________? What was lacking in the description?
  - Did you find it easy or difficult to describe water? Why?

    - Are there any disagreements (contradictions) among the groups' descriptions?
- Work with the students to consolidate their groups' descriptions onto a single class chart. If there are contradictions, include them. Tell students that they will be exploring the properties of water through a series of investigations. As they learn, they may modify this description.
- Keep the chart posted throughout this module and work with the class to agree on any alterations to the original description. If there are contradictions which are not resolved through the succeeding Learning Experiences, invite the class to devise and carryout a strategy for arriving at a definitive answer, either through experimentation, library or Internet research, or through interviewing experts.

Activity Two: Why Would I Want to Study Water?

- Preparation: Cut Handout Two as indicated into five pieces.
- Create a 'jigsaw:' Place students in groups of 5-6 students. Identify this as their Home Group. Students in each group number from 1-5 (repeating #5, if necessary). Ask them to now form new groups of like numbers. The new groups are called the Expert Groups. Distribute Sections of Handout Two to the Expert Group members, matching group number to handout section number.
- Students in their Expert Groups read the information, discuss it, and agree on how they will share their information within their Home Groups. Tell students that they will also need to explain to their Home Group members why the information they are sharing is important for everyone to know.
- Students go to their Home Groups to talk about what they have read, and why it's important.
- Debrief the jigsaw activity as a class. Record students' responses and keep posted throughout this module.
    - What did you learn that you thought was especially important to know? Why?
    - What questions do you have about water?

LE 1 Handout One

The Blue Planet, Milky Way Galaxy

http://nssdc.gsfc.nasa.gov/imgcat/hires/a17_h_148_22725.gif

LE 1 Handout Two

Water: We Couldn't Exist Without It!

Sources of data: http://www.pureinsideout.com.

1

Water: We Couldn't Exist Without It!

Can you imagine our planet without water? Seventy percent of the surface of our planet is covered by water in the form of lakes, rivers, and oceans. Water is the most common chemical in every living thing. Over 50 - 75% of the human body is water. Water makes life as we know it on Earth possible. Water also gives beauty to our planet and is an inspiration for art.

The properties of water are so unusual that scientists are still arguing over its molecular mysteries. It is the uniqueness of water that makes it a life-giving substance. There is no other molecule that has the same kinds of properties. Water is a universal solvent, which means that nearly every substance will dissolve in water. Water is unique in that the solid form is lighter (less dense) than the liquid, and therefore floats. For its molecular size, it exists, in its liquid form, over a very large temperature range, which is critical for life, since all living cells contain large amounts of water.

2

Water: We Couldn't Exist Without It!

Water is an unusual chemical in that it exists on our planet in all three states of matter: as a solid (ice), a liquid and a gas (water vapor in the atmosphere). In its liquid state, water is found as deep as 6.5 miles below the surface of the ocean. In its gaseous state, water rises in the atmosphere nearly 400 miles above the surface of the planet.

Water as both a solid and a liquid is home to many of Earth's creatures. Without the polar ice cap, polar bears could not survive. The oceans, lakes and rivers across this planet teem with life. Microscopic plankton serve as food for mammals as large as whales and produce most of the life-giving oxygen in our atmosphere. Fish, reptiles, and mammals live, bathe and play in watery environments. Birds, insects and mammals seek their food in watery environments, and rely on water for sustenance.

3
Water: We Couldn't Exist Without It!

The oceans account for the bulk of surface water on earth. Our oceans' waters protect the land from extreme changes in temperature—the ocean cools our summers and warms our winters. Ocean currents create beautiful coastlines and bring sand to our beaches. Ocean waves are a playground for many mammals, including humans. The ocean, and also rivers and lakes serve as a liquid highway for transporting goods and people around the globe.

It is remarkable that the solid form of water floats on top of liquid water. Aquatic organisms (organisms that live in water) survive winters in cold climates because of the insulating protection of ice. Penguins and polar bears depend on ice for their home base, while they swim in the ocean to seek food.

Water in its liquid phase has a property that causes its surface to form a 'thin skin.' This allows some very light creatures to actually walk on the water's surface. This stickiness of water on its surface also creates water droplets which are an essential part of the life-supporting cycle of water on our planet. Just imagine: the water that we drink today is the very same water that existed millions of years ago!

4
Water: We Couldn't Exist Without It!

Water plays many vital roles in our bodies. Water protects our bodies from temperature extremes. Heat enters our body from the environment. Heat is also produced within our body through chemical reactions. Water distributes all this heat throughout our tissues keeping the inside of our body at a uniform temperature.

Chemical reactions throughout our body—and in all living things—produce energy and nutrition for our cells. All these chemical reactions occur because water has an unusual capacity to dissolve most substances necessary for life processes.

Water delivers life-sustaining nutrients into every living cell and removes poisonous wastes from every cell.

Water is also a necessary chemical in two vital processes: respiration and photosynthesis.

5
Water: We Couldn't Exist Without It!

Water cannot be replaced on this planet. We have all the water we will ever have. Only about 3% of the water on the planet is drinkable, and 2% of that is tied up in polar ice and glaciers. So, only about 1% of the water on earth is available for humans to use and share with all other organisms.

Humans use water not only to replenish the body's supply, but also for agriculture, manufacturing, many household uses such as cleaning and cooking.

In many poor countries, the lack of clean water causes much sickness and death. While in this country, humans waste water thoughtlessly. For example, do you keep tap water running when you don't need to, such as when you are brushing your teeth?

While water is being needlessly wasted, it is also becoming more and more polluted all over the world. Consider the fact that groundwater (water that is in the soil underground), once it's polluted—whether from personal, agricultural or industrial pollutants—will stay polluted for thousands of years.

Climate change as a result of Global Warming will cause many water-related problems across the planet.

Notes to Teachers

Adjusting the LE according to students' prior knowledge
A purpose of this activity is for the teacher to assess each student's level of knowledge about the chemical and physical properties of water, therefore, it's important for the teacher to review each student's initial description and adjust the following Learning Experiences accordingly.

Instructions about the Role of the Visitor in Activity One
Before the class, the teacher arranges for someone (e.g., principal, another school staff person, or a school volunteer) to visit 15-20 minutes prior to the end of the class period to read the prepared descriptions. Inform the visitor that students have worked in groups to describe a substance. The visitor's task is to guess what the substance is. If there is lack of clarity in a description, the visitor may ask clarifying questions. Although this isn't a perfect test of how well the students have described water, the anticipation of a visitor who will try to guess what the students are describing will likely add suspense and perhaps motivate students to do their best work.

About the photograph of planet Earth
Handout One is an Apollo 17 hand-held Hasselblad (German Camera manufacturer) picture of the full Earth. This picture was taken on 7 December 1972, as the spacecraft traveled to the moon, the last of the Apollo missions. A remarkably cloud-free Africa is at upper left, stretching down to the center of the image. Saudi Arabia is visible at the top of the disk and Antarctica and the South Pole are at the bottom. Asia is on the horizon is at upper right. The Earth is 12,740 km in diameter. (Apollo 17, AS17-148-22725).

Description and image excerpted from:
http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/a17_h_148_22725.html

Learning Experience Two

Chemical Properties of the Amazing Water Molecule

Overview

Guiding Question: What are the chemical properties of water that enable and support life?

The purpose of this learning experience is for students to acquire a concrete understanding of a water molecule. In the first activity, students use clay and toothpicks to make as accurate a model of a water molecule as possible. The model must represent the precise positioning of the atoms. In the second activity the students model the polar nature of the water molecule using magnetic attraction rather than actual molecular polarity to demonstrate an important consequence of polarity, the formation of relatively weak bonds between molecules. Finally, the students use their bodies and magnets to represent how water molecules are attracted to each other.

Evaluation

Students create clay models that show the chemical composition of a water molecule and write a description in the first person of what it feels like to be a water molecule, incorporating the features of the molecular structure and polarity.

Materials

- Modeling clay in 2 colors
- Toothpicks, 2/student
- Protractors, 1 each per group of 4-6 students; at least one compass
- 2-3 reference books with diagrams of water molecules
- Optional: Access to the Internet
- Small index cards or post-its in 2 colors (1/3 of students require a card in one color, 2/3 of students require a card in the other color)
- Bar magnets, 1 per student

Activity One: Modeling of a Water Molecule

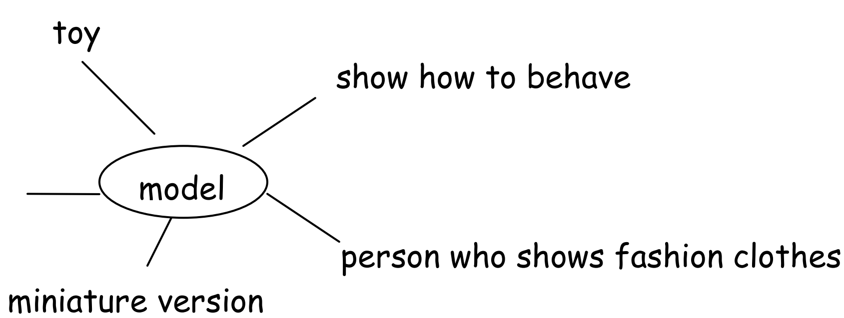
Goal: To better understand the chemical structure of water molecule through modeling.

- Explain to the students that in order to understand what makes water so special they must examine its chemical structure. Tell students that this knowledge is the key to understanding why water makes life possible on this planet.

- Ask students what a molecule is. You may need to provide a scientifically accurate definition, such as:

  Molecule - the smallest particle of a substance that has all the characteristics of that substance.

- For example, if you began with a milliliter of water (use English system of measurement only if necessary), and kept dividing the volume of water in half, you would eventually reach the point where you had only 2 molecules of water remaining. You could divide that in half, but once you had just one molecule left, you could divide the water no further.
- Each water molecule is so tiny that it cannot be seen even with a microscope. Stress to the students that because it's impossible to actually see molecules of water, students will be creating models of water molecules in a way that will help them understand its unusual properties. Scientists often create models to help understand things that are otherwise very difficult to imagine. In high school, students will learn the atomic theory and develop a more scientifically accurate understanding of atoms and molecules.
- Be sure students understand the use of the word, model, in a scientific sense. Write the word, model, on the board and ask students for definitions; refer to a dictionary, if necessary. Write their definitions.



Offer a definition appropriate for a scientific model, such as, *a stylized representation* (adapted from *Webster's New Twentieth Century Dictionary Unabridged, second edition*). Talk with students about what the word stylized means: to represent something according to an accepted style, rather than as it appears in nature. To demonstrate this definition, ask students to draw a picture of a person as quickly as they can and with as few lines as possible. Some students will inevitably draw a stick figure. Talk about how we all recognize a stick figure as a person, even though it is not at all anatomically (scientifically) correct. Ask where students have seen stick figures used (e.g., public restrooms). **It's important that students understand that a model is just a convenient approximation, so that when they make models of water molecules,**

they will accept them only as models, and not what water molecules really look like in nature.

- Write on the board:

Water molecule

- Ask students if they know what molecules of water are made of (they may even know water as H_2O). Write the names on the board. If students know H_2O, refer to the H and O as scientific shorthand for hydrogen and oxygen, respectively.

oxygen = O   hydrogen = H

- Ask students what atoms are. Write on board. If necessary, provide a definition, or revise students' definitions to ensure scientific accuracy:

atom - the smallest particle of an element that has all the characteristics of that element

The smallest particle of hydrogen is a single hydrogen atom. The smallest particle of oxygen is a single oxygen atom.

- Tell/remind students that atoms join together in chemical reactions to form molecules. Hydrogen and oxygen are very tiny atoms. In fact, hydrogen is the smallest of all the elements. It takes two hydrogen atoms and one oxygen atom to form one molecule of water. Write this on the board:

In a chemical reaction,
1 oxygen atom and 2 hydrogen atoms combine to form 1 water molecule:

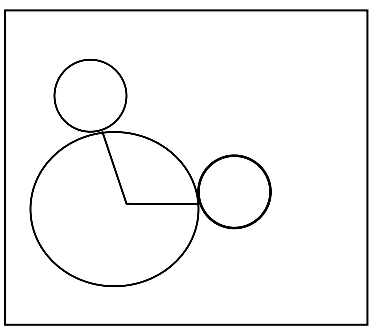
Scientists use standardized shorthand to describe chemical reactions. It's called a chemical equation:

$$1\ O + 2\ H \rightarrow 1\ H_2O$$

Note: Oxygen and hydrogen exist in nature as molecules consisting of two atoms each, O_2 and H_2, but unless students already know this, it's not necessary to be this accurate. It's also not necessary for students to know that the mathematically balanced equation is: $O_2 + 2H_2 \rightarrow 2\ H_2O$.

- Distribute the clay and toothpicks, two pieces of each color of clay and 2 toothpicks to each student.

- Tell students to make clay models of two hydrogen atoms and one oxygen atom. Remind them to make the hydrogen atom much smaller than the oxygen atom.
- Ask students to combine the atoms to form a water molecule, using the toothpicks to represent the bonds that form between the atoms, holding them together. Don't give them any information about the shape of the water molecule.
- Ask the students to look at each other's models and discuss the variations they see among all the models. Students will notice that the size of the atoms varies. Although the size of the atoms is difficult to imagine because they are so very tiny, what should absolutely be consistent in the models with regard to size? Students should recognize that the two hydrogen atoms must be the same size. All hydrogen atoms are alike and should therefore be the same size. The hydrogen atoms should also be smaller than the Oxygen atom. In addition to variations in size, be sure students notice that the positioning of the hydrogen and oxygen atoms is different. Tell students that the position of the atoms in a water molecule is very exact.
- Tell students that to complete this model, they must position the hydrogen atoms next to the oxygen so that the bonds form a 105^o angle. Draw on the board an approximation so students can envision how the angle is formed:

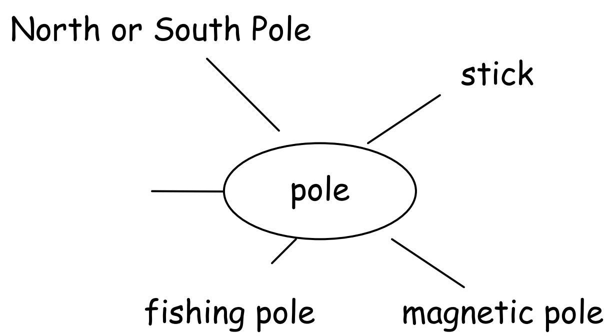


- Place the students in small groups. Ask each group to select one of their water molecules to work with. Remind them that they want a molecule as accurate as possible and therefore they must be certain the hydrogen atoms are the same size. Challenge students to position the toothpick bonds on one of their water molecules to form exactly 105 degrees, in whatever way they can. Invite them to ask for whatever tools they require. [Some possibilities: Use a compass to create the 105-degree angle between the toothpicks; draw a picture of the angle using a protractor or compass and place the clay model over the picture, moving the toothpicks until they match the drawn angle; use one of the reference books or the Internet to find a scientific diagram of a water molecule and place the clay model over the diagram to align the toothpicks into the correct position.]
- Ask groups to present their models to the class and describe how they constructed the bonds to form a 105^o angle.

Activity Two: Simulating the Polar Nature of Water Molecules

Goal: To understand what a polar molecule is and how this property of polarity affects the behavior of molecules

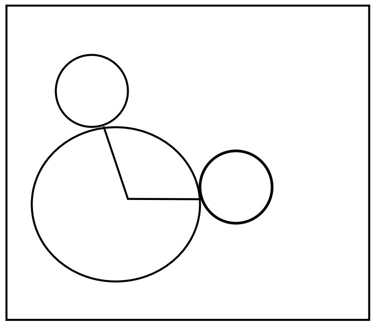
- Tell students they again will model the formation of water molecules from atoms of hydrogen and oxygen, this time using their bodies, so they can explore another characteristic of water molecules: *polarity*. Ask students to offer examples of how the word 'pole' is used in ordinary life, in geography and in science. You may want to create another word map.



- Distribute a bar magnet to each student. Students will work with a partner to explore the properties of a magnet.
- Ask students what they know about magnetism. Post answers. Be sure students state that like poles repel and unlike poles attract. Collect magnets, or have students set the magnets aside.
- Explain that water molecules also have two poles, but they are not magnetic poles. Draw a water molecule on the board and represent the poles with a + and -.

A water molecule is polar:

+ pole



- pole

- Explain that in a water molecule, each of the hydrogen atoms has a positive *electrostatic* charge and the oxygen atom has a negative electrostatic charge. (Refer to information in the Box below for an explanation of the term electrostatic. If students are not already familiar with the terms protons and electrons, you'll need to decide, based on the level of interest of your class, how deeply you want to develop their understanding about electrostatic charges.)
- Remind students that when the hydrogen atoms bond to the oxygen atom, they form the special 105^o angle. The result is that the positively charged hydrogen atoms are positioned fairly close to each other. This makes their end of the molecule what scientists call a positively charged pole, and the opposite end (where the oxygen atom is located) a negatively charged pole. These charges are electrostatic, but the plus and minus charges attract and repel in the same way that the north and south poles of magnets repel and attract.

Note on static electricity:

Students are already familiar with electrostatic charge, often called static electricity. Students may be able to offer an example of when they have observed static electricity, such as getting a shock after walking on a rug, then touching a metal doorknob, pulling off a winter cap and seeing their hair stand on end, rubbing a cloth against a balloon and then noticing how the balloon will adhere to the wall. Lightening is another example of the effects of electrostatic charge.

Simple explanation of electrostatic charge: All atoms contain protons, which have a positive charge, and electrons, which have a negative charge. Like charges, whether positive (+) or negative (-) repel each other, and unlike charges attract. Normally, there are an equal number of protons and electrons in every atom, which cancel each other out, making atoms neutral of charge. The electrons are always positioned on the outside of atoms, and may be removed under certain circumstances. When electrons are removed, the atoms have positive charge. Some kinds of atoms have a stronger hold on their electrons than other atoms.

Simplified explanations of what happens when we experience static electricity: In the example of the hat, when you pull the cap off your head, many electrons from the atoms on your hair are also pulled off your hair. Therefore, the atoms on your hair now have a positive charge. The strands of hair repel each other, because like charges repel. That makes your hair stand up and separate. In the example of getting shocked, as you walk across the rug, you drag electrons off the rug. The extra electrons on your body are attracted to the metal door knob and actually can ‘jump’ from your hand to the knob, creating a small electric current. If the room is dark, you may be able to see the electrical spark between your hand and the knob.

- For this activity, ask students to imagine that the north pole of a magnet is a positive (+) charge and the south pole is a negative (–) charge. Write this on the board for easy reference during the activity:

+ charge | N S | - charge

Note: For this activity, all the students will be standing close to each other. Move furniture as necessary to create an adequate space.

- Tell students they will create another model, this time of how water molecules interact with each other. By creating this model, they will discover something very unusual that happens whenever water molecules get close to each other.
- Assign students numbers from 1 to 3 (for the 2 H and an O to form a water molecule) until everyone has a number. If there is an extra #1 or a #1 and a single #2 left over, ask those students to serve as the 'energy' that is needed to create water molecules. If there are no students to serve in this role, designate yourself as the energy. All the #1s will pretend they are oxygen atoms. Give each of them the same colored index card. Students write a large letter O in their card, to represent the word oxygen. The #2s and #3s are hydrogen atoms. Give each of them the other colored index card and ask them to write an H on their card. Give each student a bar magnet.
- Ask students to move <u>slowly</u> and <u>silently</u> around the open space you've created in the classroom, holding up their cards so everyone can read whether they are an atom of oxygen or hydrogen. ***It's important that students are silent, since you'll be giving directions throughout this activity.***
- While students are quietly walking, tell them to listen for two claps, which will represent the energy needed for the chemical reaction that will form water molecules. When you (or your students who are representing energy) clap twice, students form molecules of water. Tell students when they combine, they should hold onto each other's index cards to represent the bonds that have formed between the atoms. Remind students to remain silent so they can hear your instructions. You and the students representing energy can move among the students to help form the molecules.
- Instruct students to position themselves as the atoms within their molecules to estimate the 105^{o} angle. Ask groups how they estimated. If necessary, remind students that a right angle is 90^{o}. The hydrogen atoms can move apart slightly from a right angle to achieve approximately 105^{o} angle. You and students representing energy can move from molecule to molecule checking for an approximation of accuracy in their positioning.

- Tell students that they will now model how water molecules interact in a glass of water.
- Instruct each hydrogen atom to hold out the bar magnet so that the N pole (positive charge) is facing outward. The oxygen atoms would do the reverse, holding out the S pole (negative charge). Be sure students understand the reason why they are holding the magnets in a certain way.
- Ask the molecule groups to move close to each other—close enough so that the magnets naturally attract each other and touch one other magnet.
- Ask students to look around the room and describe what has happened. Give students the expression, 'hydrogen bond,' to describe the connections that have been made between molecules. They should be able to see that the oxygen atoms have each connected with a hydrogen atom because of the attraction of the (+) and (–) poles.
- While students are still connected to each other, remind students that they have created a **model** of how water molecules interact in a glass of water. Invite students to look carefully, creating a strong mental picture of how their molecules look, because many of the mysterious things that water does are explained by this tendency of water molecules to stick to each other.
- Reiterate that the attraction of the positively charged hydrogen to the negatively charged oxygen is called a **hydrogen bond**. Tell students that hydrogen atoms will also form bonds with other atoms or molecules that have a negative charge. Soon they will see how that happens, and how important hydrogen bonds are. **Hydrogen bonds are the key to unlocking the mysteries of the water molecule!**

Activity Three: Recapping What We Have Learned

- Give students three minutes to write about what they learned from the two models they created: a clay model of a water molecule, and the students themselves holding magnets to make pretend they are electrically charged water molecules in a glass of water, sticking to each other because of their polarity. Allow another three minutes for students to talk with a partner.
- Class discussion:
    - How did each model help you better understand the molecular nature of water?
    - What is one thing you learned about water? Post responses and keep these posted throughout this module.
- Writing activity: Imagine you are a water molecule.
    - What are you made of?
    - What do you look like?
    - How do you act when you get near other water molecules?
    - What do you think is your best feature? Why?
- Place students in groups of three. Students will take turns reading what they have written.
- Review new terms, e.g., polar molecule, hydrogen bond

Notes to Teachers

Modeling can promote student understanding.

The National Science Education Standards comment on young students' (K-8) lack of capacity to understand such an abstract concept as atomic theory. Often, States set middle grades standards for students to know about atoms and molecules. It is possible through modeling for students to understand the features of a water molecule that make life possible on this planet. It's important to emphasize that although models are often created by scientists, these representations are not exact, but do help us understand things that are otherwise very difficult to comprehend, or to draw exactly as they appear in nature. Students will develop a full understanding of atoms and molecules when they are in high school. The analogy that is used in this LE is the way that human figures are sometimes drawn as stick figures that are universally recognizable as people even though they are not scientifically accurate representations.

Learning Experience Three

Exploring the Physical Properties of Water

Overview

Guiding Question: What are the physical properties of a water molecule?

The purpose of this learning experience is for students to understand key physical properties of water that result in its unique ability to support life on Earth. The properties investigated are: water as a solvent, the capacity of water to hold heat, the cohesive nature of water molecules, and the comparative density of liquid and solid water.

Evaluation

Students will demonstrate their knowledge of the properties of water investigated in this Learning Experience. For each property, students will identify at least two consequences that make life possible on Earth. Demonstrations can be presented in writing or orally (including a PowerPoint or other visuals); through a skit, song, or drawing.

Materials

Refer to each activity for required materials.

Materials for Activity One, Part A

First day, for each group:

- Small clear plastic cup (6 or 8 oz.)
- Salt
- Measuring spoon, 1/4 tsp
- Measuring cup marked into ounces/milliliters or graduated cylinder
- Supply of water
- Container for disposing of used salt water

Second day: materials vary, depending on the experimental design created by each group

Materials for Activity One, Part B

For each group:

- Eight pieces of thin wire cut to 3”(7.6 cm) per group of 4-5 students, contained in an envelope (used also in Activity Three)
- Five plain wooden toothpicks which have been colored on one end with a marker

- One 4x6 index card or ¼ sheet of 8.5x11" paper per group
- One protractor per group (ideally, one protractor per person)
- Clay model of water molecule (from Learning Experience Two)
- Large chart paper and markers

Activity One: Why is Water Called a Universal Solvent?

Goal: For students to understand that the polar nature of the water molecule enables most substances to readily dissolve in water.

Introduce Activity One by telling students that <u>more substances can dissolve in water than in any other liquid</u>. Because of this remarkable capability, all the chemical reactions that occur in living things are happening because the chemicals are dissolved in water. Also, living things could not obtain nutrients or get rid of wastes if all these chemicals couldn't be moved into and out of living cells dissolved in water. Tell students that they will first explore factors that affect how substances dissolve in water. In the second activity, they will discover the secret to water's ability to dissolve so many substances.

Part A: Exploring the solubility of salt in water

Note: This activity will require 2 days—on the first day, students design their experiments; the teacher and students will then need at least overnight to obtain the needed materials, before students conduct their experiments.

First Day

- Writing on the board, review the meaning of the words <u>sol</u>ubility and dis<u>sol</u>ve before students begin. Students should observe that each word contains the three letters "<u>sol</u>" (coming from the Latin verb '<u>sol</u>vere' meaning to melt or loosen). You may want to create a word map, with 'sol' in the center. Add to the map other words that scientists use to talk about solubility: <u>sol</u>ution (usually a combination of solid particles mixed completely within a liquid), <u>sol</u>vent (the medium in which something is dissolved) and <u>sol</u>ute (the substance being dissolved). Add the everyday words <u>sol</u>ve and <u>sol</u>ution, which also have the same Latin root. Ask, How can the Latin definitions of 'melt' or 'loosen' apply to all these words?
- Place students in groups of 4-5 and number from 1-4/5. Assign roles:
    1. Recorder
    2. Materials collector (1 or 2 persons)
    3. Measurer
    4. Reporter
- Ask #2 students to gather for their group: the cup, salt, spoon, and measuring cup or graduated cylinder. Make available only water at room temperature. Students have 15 minutes to use the materials to explore the solubility of salt in water.

- Ask groups to select a spokesperson to describe what they observed. Post observations. Encourage specificity and thoroughness, as well as the use of the terms: dissolve, solution, solubility.
- Ask students to each write at least one question they have, based on their exploration. What more do they want to know about mixing salt and water? Post questions and talk about which ones might be answered by doing an experiment. Work with the students to reword questions, when possible, to make them researchable. For example, the question: “How much salt will dissolve in hot water,” would be improved by asking, “How much salt will dissolve in a <u>given quantity of</u> hot water?” Why is the latter more scientific?
- If any questions pertain to “why” salt dissolves in water, tell students the class will investigate that question together in the next Activity.
- Ask each group to select a question they want answer by conducting an experiment. For example, using the above question:
  - Does the temperature of water affect how much salt will dissolve?
  - How much more salt will dissolve in hot water than in cold water?

> If you are concerned with the quality of the questions students created, add an intermediate step: Continue to develop potential questions with your guidance and then allow the groups to select the question they want to investigate from the list.

- Each group writes a design for an experiment to answer their question. Tell students before they begin that they need to design an experiment which they can conduct here in the classroom, using readily available materials and equipment. They should create a list of these supplies and equipment. On chart paper or the board, list the following statements. Tell students that need to consider these criteria:
  - The instructions should be written clearly enough that another group could follow them and get the same results.
  - There should be a plan for collecting the data in an organized way.
  - The experiment should use readily available materials and equipment.
  - Variables should be controlled so that students are testing only one variable at a time. (A question to ask: “Is this a fair test?”)
- Students present their designs and list of needed materials to the class, and obtain feedback. The extent of the discussion will vary depending on how well informed students are about designing and conducting experiments. It’s important that students use scientific methods, and think and behave like scientists.
- Students and the teacher negotiate on what materials the teacher will provide, and what the students in each group will bring.

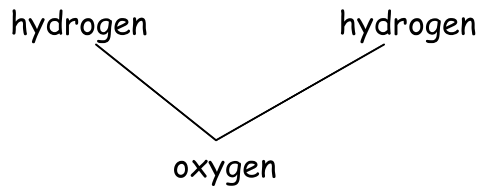
Second Day

- Students conduct their experiments and record results. Help each group to construct a data table and create a graph or other appropriate visual to present the data in the most meaningful way.
- Each group reports on their results: whether they were able to answer their research question—and, if so, what the answer was. The group should report on problems they encountered and further questions they now have.
- Ask students to challenge any conclusions that were not supported by observations and the data.
- Create a class list of what students learned about the solubility of salt in water.

Part B: Creating a scientific model to show why substances dissolve readily in water

- Ask students to explain why they think salt, or any other substance dissolves in water. Accept and post all answers. Explain that the scientific explanation is abstract, since we cannot see what the molecules are actually doing. Therefore, once again we will create a model to understand what is happening at the *molecular level*. As a reminder, ask for a description of a *scientific model*.
- Introduce the expression, 'universal solvent.' Ask students to talk with a partner, using their understanding of the terms universal and solvent to describe what they think the expression means. Share responses with the class. Tell students that more substances will dissolve in water than in any other liquid. This feature makes water very important in living things. All the nutrients and wastes that organisms produce move into and out of cells because they are dissolved in water. Although the term 'universal' is used, it does not mean that <u>every</u> chemical dissolves in water.
- Place students in groups of 4-5. Distribute the pieces of wire and the index cards (or paper) to each group. Instruct each student to use a single piece of wire to create a simple model of a water molecule. Allow time for exploration. If necessary, remind students of stick figures. Some students should figure out that they can create a stick figure of a water molecule by bending a wire half-way down its length to create a V shape slightly more obtuse than a right angle. If no one arrives at this solution, demonstrate it for the students and discuss why it is similar to a stick figure of a person or animal—what is 'accurate' about it and what is not? Give protractors to groups that request them to precisely create the 105^o angle. Other groups might be satisfied with an approximation of an angle slightly more obtuse than a right angle. Discuss groups' models.
- Draw a stick figure of a person on the board, and label the arms, hands, legs, head, and feet. Now ask students to draw and label their wire model of a water molecule. Where are the two hydrogen atoms located? Where

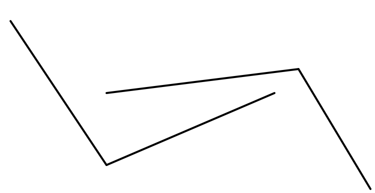
is the oxygen atom located? You may want to tell students that when they read about water molecules, they may see them referred to as V-shaped.



- Ask students to compare a stick figure of a person to a clay model of a person. What do they have in common? How do they differ? Hold up a clay model of a water molecule. How does the clay model differ from the V-shaped wire model? Which model is closer to reality? Why?
- Now ask groups to imagine that their index card is a model of a drinking glass. Ask students to create a model of a glass of water, using wire molecules to show how water molecules would arrange themselves in the water. Challenge them to use as many of the molecules as they can to completely 'fill' the glass, but to keep the model as scientifically accurate as possible. Help groups as necessary by posing questions, rather than correcting their mistakes (see text box below).

> Students should only be able to place 6-7 molecules on the card, if they remember that water molecules are bipolar. Thus the 'arms' of a molecule cannot be close to arms of another molecule nor the apex close to another apex. Students should align the molecules so that a hydrogen atom of one molecule is positioned near the oxygen atom of a neighboring molecule. There can be no places where oxygen is near oxygen, and hydrogen near hydrogen.
> Also, the space inside the V is really not empty, but almost completely filled with the oxygen atom. Keep the clay model available to remind students of a more realistic model.

- Ask the group that finishes first to create a drawing of its model on chart paper.
- Discuss the models:
    - Why must the molecules be arranged so that oxygen atoms are near hydrogen atoms?
    - Why can't there be hydrogen atoms close to each other, oxygen atoms close to each other?
    - Why couldn't they arrange two molecules like this?



  - How many molecules of water can they fit in their glass of water?
  - Why are there spaces in the glass?
- Tell students that, like water molecules, salt molecules are polar, as are many other kinds of substances that dissolve in water. The salt they have been using is called sodium chloride. Each molecule is made of one sodium atom and one chlorine atom:

Sodium atom = Na   Chlorine atom = Cl

$$Na + Cl \rightarrow Na\,Cl$$

sodium chloride molecule $Na^{+}\,Cl^{-}$

Note that the sodium has a positive (+) charge and the chloride has a negative (-) charge.
One more important detail: When sodium chloride enters water, the molecule dissociates—or breaks apart into a positively charged *sodium ion* and a negatively charged *chloride ion*. (Chlorine is called chloride when it has a negative charge.)

$$Na^{+}\,Cl^{-} \rightarrow Na^{+} \text{ ion and } Cl^{-} \text{ ion}$$

- Give each group the toothpicks. Ask them to imagine that a toothpick is a molecule of sodium chloride. The sodium is one end and the chloride the other end. Agree on which end represents sodium and which represents chloride. Post this information for easy reference.
- Instruct students to create a model of salt water. Circulate, posing questions if necessary that remind students, the salt molecule will break apart in water into charged ions (students should break the toothpicks and arrange the halves among the water molecules). That their model should take into account the behavior of polar atoms [the charges attract: hydrogen (+) to chloride ions (-) and oxygen (-) to sodium ions (+)].
- Note to Teacher: save the wire models for a later investigation.
- Questions for discussion:
  - Why would charged particles dissolve so easily in water?
  - Describe the molecular reason why water is a universal solvent.
  - Extension: Does the volume of water necessarily change when the salt dissolves in it? Why or why not? *If there isn't very much salt, the ions will simply fit in the spaces among the water molecules. This may be difficult for students to imagine in a two-*

dimensional model, so remind students that in the real world, the water and salt occupy a three-dimensional space.

Materials for Activity Two

Quantities assume three groups of students with no more than 5 students in each group. If the class is larger, create one or more additional groups and adjust materials accordingly.

- Three hot plates
- Three cooking pots of same size and shape
- Three Pyrex beakers of same size or 1-cup Pyrex measuring cups that will fit easily within the pots (these are the test containers and should be identical in size and shape)
- Three thermometers—either scientific or cooking thermometers that can be used to measure temperature from 0^{o}C (32^{o}F) to 100^{o}C (212^{o}F); again, it is best that they are the same
- Isopropyl alcohol (pure alcohol gives best results, but rubbing alcohol can be used with less dramatic results)
- Water (sufficient for simmering water baths, optionally ice-water baths, and about 8 ounces for testing)
- Optional extension of experiment: Three containers of ice water (plenty of ice) large enough for the Pyrex beakers or measuring cups to fit inside (of equal size)
- Plastic wrap and rubber band to cover one of the beakers or measuring cups
- Three timers to measure a total of 10 minutes and be able to easily track the time elapsed at one-minute intervals
- Handout One (chart to record data)
- Large chart paper with graphing lines, 3 different colored markers

Activity Two: How Much Heat Can Liquid Water Absorb Before It Changes to a Gas?

Goal: For students to know that because of hydrogen bonding water has a large capacity for absorbing heat without an increase in temperature.

- Introduce the activity by telling students that water has another very unusual property: its *heat capacity* is very great. Ask students to try to figure out what this expression means. In scientific vocabulary,

Heat capacity refers to the amount of heat energy that can be put into a substance before the temperature of the substance increases.

A more scientific definition: Heat capacity means the amount of heat energy that must be put into one gram of a substance to get a one degree rise in temperature.

- Review / clarify the definitions of energy, heat and temperature.
  - Students should already know that temperature is a measure of molecular motion. Heat energy increases the motion, actually vibration, of molecules. The higher the temperature, the greater the vibration.
- Ask students, At what temperature does water freeze and boil? Tell students that this broad range is unique. Other molecules of similar size to water freeze at a higher temperature and boil at a much lower temperature. <u>Water is unusual in that it remains a liquid over a very wide range of temperature</u>. Discuss: In what ways would living things be affected if water were not a liquid at such a wide range of temperatures?
- Tell students that the oceans, which cover about 75% of the surface area of the planet, are the main reason why the climate on earth is mild enough for life to exist. Ask: What heats the ocean? (sun) When the sun heats the ocean, the water has an unusually high capacity to absorb this heat—there is just a small increase in water temperature when it is heated. Therefore, the temperature of all bodies of water remain relatively constant. This property protects life on this planet. Otherwise, there would be rapid and extreme temperature changes and Earth would not be inhabitable. The climate along coasts is particularly moderated, influenced by the buffering effect of the ocean. Discuss students' experiences with the buffering effect of water (e.g., day and night temperatures in an inland desert can vary dramatically).
- Tell students that they will be working as a class to design and carry out an experiment to investigate the heat capacity of water compared to other substances.
- You may tell students that they already have learned enough about the molecular nature of water to understand <u>why</u> water is a liquid over such a broad range of temperature—said another way: why its heat capacity is so large. Withhold the explanation until the end of the activity, unless student(s) already have the knowledge and want to discuss it.
- Design an experiment to answer this question:

How does the heat capacity of water compare
to two other common substances, alcohol and air?

- Place students in groups of 4-5 to discuss: What are some ways you could compare the heat capacity of water to other substances? Ask each group to report its ideas to the class. Record the ideas so they are visible to all. Help students by reminding them of the definition of heat capacity. What would they be measuring? How could they measure it?

- The planning for this experiment will depend upon the students' ideas. Issues that need to be discussed are listed below. You may want to allow students to work on their own, then post these questions and give students additional time to refine their design before discussion.
    - What tool would be used to measure change in temperature? *thermometer*
    - How could we easily and safely add energy (heat) to each of the substances? *Hot plates are safer than an open flame, and easier to control. The choice of substances should be guided by how easy it would be to measure temperature changes, e.g., it would be difficult to measure the temperature of a solid.*
    - How many substances should be tested? *A minimum of 3, water and two other substances. Testing just one other substance would be very limiting in terms of data collection*
    - What aspects (variables) of the experiment must be kept exactly the same for measuring the heat capacity of each substance? Examples:
        - Use the same thermometer for each or different thermometers that you test first to see if their readings are the same (if not, make a note of the difference and you can accommodate this difference by adding or subtracting degrees from the readings).
        - Everyone should be very careful to read temperatures accurately.
        - Provide exactly the same amount of heat to the three substances. *Discuss why placing the containers of test substances in a simmering pot of water ensures the same amount of heat exposure.*
        - Use exactly the same volume of each substance.
- Unless students create a reliable design, show students the equipment and supplies that you have made available to use. The test substances easy to use are water, alcohol and air. Considering this equipment and the three test substances, the experiment could be designed as follows. Work with the class on the directions to be sure they are understood. Accept alterations or refinements which the students suggest that still ensure there is only one variable being tested (i.e., change in temperature) and that all other variables are controlled so the experiment is "fair" to each test substance (e.g., amount of test substance used, source of heat). Once there is agreement on the design, make the steps visible to all throughout the experiment. Suggested design:
    1. Divide the class into groups of 4-5, each group assigned to test one of the substances. If there are more than three groups, assign more than one group to test the same substance. Assign roles within groups: time keeper, temperature reader, data recorder, depending on the size of the group make 1 or 2 students responsible for supplies and set up. Give the students time to get supplies and get

organized. Timekeeper will know how to set timer to 10 minutes and tell when each minute has elapsed. Temperature reader will be checked by the group to be sure the temperature is read quickly and accurately when time is called at the end of each minute. *While students are getting organized, teacher will plug in the hot plates, place the pots of water on top and begin to heat the water to attain a low simmer. Distribute Handout One to each group for recording data.*

2. Fill the measuring cup or beaker almost to the top with alcohol or water. For the air sample, simply cover the cup or beaker with plastic wrap secured with a rubber band; make an opening in the plastic wrap just large enough to insert the thermometer.
3. Insert a thermometer in each test substance. Record the beginning temperature.
4. Time keeper sets timer at 10 minutes while one group member places the container, with the test substance, in the simmering water.
5. At the end of each minute, the timekeeper tells temperature reader to read and report temperature. Recorder enters the data in the chart.
6. Optional extension: Record the rate at which each substance <u>loses</u> heat by immersing the cup or beaker with the test substance in a bowl or pot of ice water. The same size container of ice water is used for each substance. Begin reading the temperature at the moment the test begins, and then each minute for 10 minutes.

- As a class, graph the data. Use a different colored marker for each test substance, using the same graph to plot all the data points for the three test substances so they can be easily compared. Include a key on the chart.
- Discuss results:
    - What can we do to make the data more visible and easy to read? *Connect the dots, drawing a line for each of the three sets of data.*
    - How do you explain the differences in data? Which substance had the greatest heat capacity? Which had the smallest?
    - How do these results explain why the night and day temperatures of an inland desert can vary so greatly, while on the coast the temperature doesn't fluctuate nearly as much?
    - How do these results help explain why life is possible on earth? *The examples range from explaining why the temperature on Earth is tolerable for living things to why the temperature within living cells stays within a safe range for chemical reactions to take place even when the external temperature fluctuates.*
- Explain and discuss why water has a high heat capacity. <u>The answer is in the hydrogen bonds</u>. Review hydrogen bonds (*weak electrochemical attraction between water molecules because of their polarity that holds the molecules together*). Two things are happening (you may want to illustrate

by having 2 students each represent a water molecule (or using 3-D models of water), while you represent the heat energy)

1. Heat energy increases the vibration of molecules. The higher the temperature, the greater the vibration. Because the hydrogen bonds are holding the water molecules together, it takes more heat for water molecules to vibrate compared to molecules of most other substances, where the molecules are all separate from each other.
2. Some of the heat energy is used up to break the hydrogen bonds. Only after the bonds are broken, can the remaining heat energy cause the individual molecules to vibrate more rapidly.

Materials for Activity Three

Part A: For each pair or small group

- Penny
- Cup partially filled with water
- Cup partially filled with alcohol
- Eye dropper or pipette
- Paper towels

Part B: For each group of 3-5 students

- Plastic drinking straw
- Glass tubing of varying bore diameters, including capillary tubing
- Small container of water with food coloring added
- Clear cup or beaker
- Rulers to measure millimeters
- Handout Two

Activity Three: Exploring the Properties of Cohesion and Adhesion

Goal: For students to know that water's properties of cohesion and adhesion are an effect of hydrogen bonds. These two properties help support life processes.

Part A: What causes cohesion of water molecules?

This activity is designed as a review because students most likely have already engaged in a science activity at an earlier grade to demonstrate the property of cohesion, and may recall the term. Adapt this activity according to students' prior experience. There are more demonstrations and inquiries available in the elementary module, *Investigating the Mysteries of Water I*, and on the Internet, e.g., http://www.biologylessons.sdsu.edu/ta/classes/lab1/TG.html

- Distribute materials to pairs or small groups of students.
- Ask students to use the dropper to place water slowly onto the penny. Students also use the dropper to place alcohol slowly onto the dried penny. For each, students draw what they observe and agree on an explanation.

- Class discussion:
  - What did you observe? How many drops of water could you place on the penny before the water spilled off the penny? How many drops of alcohol?
  - Where have you seen other examples of how water seems to stick to itself? *Droplets of water on a leaf of a plant after it rain or on waxed paper, overfilling of a glass of water, getting paper clips to float on the surface of water.*
  - Water seems to actually form a skin around itself. Why does the water exhibit this unusual behavior? If students can't explain this, remind them of the polar nature of the water molecule. Ask how this polarity could explain what they observed. *The water molecules form hydrogen bonds which hold the molecules together.*
  - What natural force eventually causes the water to separate? *Since hydrogen bonding is relatively weak, gravitational force eventually has an affect on the accumulated water.*
  - The scientific term for this behavior of water is c*ohesion.*
  - The scientific term for the 'skin' that forms around the surface of water is *surface tension*.

Part B: What is adhesion and what role does it play, sometimes along with cohesion, in living systems?

Adapt this activity according to level of students' knowledge of adhesion.

- Ask students to talk with a partner about how the blood is able to circulate throughout our body, which includes blood actually rising up our body against the force of gravity. *Result of pumping action of our heart*
- Now ask students how the leaves at the top of a mature oak tree receive water*. It is unlikely that middle grades students can provide a scientific explanation for this phenomenon, which includes the processes of cohesion of water, adhesion of water to the woody xylem vessels, and the difference in water pressure created by transpiration of water from the leaves.*
- Tell students they will be investigating a behavior of water that helps explain how leaves obtain water from the soil.
- Students explore the adhesive property of water using Handout Two.
- Students discuss in their group: If water molecules are attracted to each other because of their polar nature, how can you explain water moving up a paper towel, or up a straw or other tube? Consider the reasons students offer. If not mentioned, tell students that they already know that water isn't the only substance that has (+) and (-) charges. What other substance do they already know about? *Sodium chloride* There are many substances that have electrochemical charges, such as plastic, and paper.
- Students work in their groups to try to explain the movement of water in their investigations using their knowledge of (+) and (-) electrochemical

charges. *The (+) and (-) charges on the water molecules must sometimes be more attracted to the (+) and (-) charges on other substances.*

- Ask students if they know what the term adhesion means. What are some words that sound similar to adhesion? *Students will probably mention adhesive. Discuss what the term adhesive means and examples of how it's used.*
- Introduce the scientific definition of adhesion:

Adhesion is the attraction of molecules of one substance to molecules of another substance.

- Students work in their groups to create an explanation for how adhesion and cohesion could help water move from the soil to the top of a tree. A scientific explanation follows. However, students should be able to figure out that the water would move up the tree as it did the capillary tubing and paper towel, through the force of adhesion. Cohesion would tend to keep all the water moving up the tree. Mediate students' discussions, as necessary, to help them solve the problem.

> *Simplified scientific explanation*
> *It's not only adhesion and cohesion that deliver water up a plant. There is another force at work as well. Here is a simplified explanation:*
>
> *Trees contain vessels not completely unlike our blood vessels. Arteries carry nutrients dissolved in blood throughout our body. In a tree, a woody vessel called xylem transports water and nutrients from the roots to the leaves. How does this happen, against the force of gravity? Adhesion and cohesion of water molecules create a force called capillary action. Also, as water evaporates from the plants' leaves (a process called transpiration), air spaces are left. This space increases the tension on the water in the xylem. Both the force of capillary action and this tension help move water all the way from the root up to the top leaves of a tall tree.*

- Tell students that the force of adhesion is being studied by scientists to create more effective medicines and to understand many of the unexplained molecular mysteries of living systems, which will lead to better treatment of many illnesses.

Materials for Activity Four

- Envelopes containing the bent wires from Activity Two, Part B
- 1 4x6 index card per group

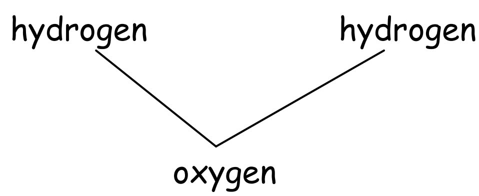
Activity Four: Why Does Solid Water Float on Liquid Water?

The purpose of this activity is for students to *discover* that water molecules change their shape, taking up more space, when water goes from the liquid to the solid state. As a result, ice is less dense than liquid water. The activity allows for an abstract concept to be experienced concretely.

- Pose to students a concept that they already know through observations: Water freezes at the surface of bodies of water and the frozen water, or ice, remains floating on top. This is another unusual property of water that helps make life possible on Earth. Explain that the ice that forms on a body of water insulates the water below, protecting the liquid water from losing heat in very cold weather. Because of this insulation, life processes can continue underneath the ice. You also may want to explain that Ice and snow moderate the changes in temperature from one season to another. In the fall, water molecules in bodies of water release heat as they freeze, warming the air above. The reverse happens in the spring. Heat from the air is taken in by ice and snow, causing them to melt. The mystery is, why <u>does</u> frozen water float on liquid water?
- Place students in groups of 4-5. Students discuss:
    - What happens when matter changes its state from solid to liquid to gas?
    - What substances can you think of that exist on Earth as a solid, a liquid and a gas?
- Invite each group to create an illustration on chart paper to accompany the writing. Post charts and discuss students' explanations and drawings. Students should know that:
    - Increasing heat energy causes changes in the state of matter, from solid to liquid to gas.
    - As heat energy encounters molecules, the energy causes the molecules to move more rapidly, or vibrate—the more heat, the more rapidly the molecules vibrate, bumping into each other and bouncing off each other, moving further and further apart. In a gas, the molecules are furthest apart; in a solid the molecules are closest together.
    - Matter generally becomes denser as it changes from gas to liquid to solid state because the molecules move slower and slower and are packed more and more closely together.
- <u>Water is an exception</u>. Ask students to write an explanation of why water in its solid state actually floats on liquid water, rather than sinks. Invite each group to create an illustration on chart paper to accompany the

writing. Post charts and discuss students' explanations and drawings. At a minimum, students should know that solid water, or ice, is less dense than liquid water. Students may also be able to describe what is meant by density—that the particles or molecules of water are more tightly packed together in the liquid state than in the solid state. The question is: Why are the molecules further apart in the solid state than in the liquid state? Tell students they are going to figure out why ice floats on water. Because the reason why ice is less dense than liquid water is very complicated, they will again create a scientific model to figure out the answer.

- As a review, ask for a description of a *scientific model*. Distribute an envelope with the bent wires and the index card or paper to each group. Ask students to again describe how the bent wires represent water molecules.



- Ask students to once again imagine that the index card is a two-dimensional model of a drinking glass. Students create a model of a glass of water, using the wire models to show how water molecules would arrange themselves in the water. Reminders: polarity requires that a hydrogen atom of one molecule be positioned near the oxygen atom of a neighboring molecule; there can be no places where oxygen is near oxygen, and hydrogen near hydrogen. Also, an arm of one molecule can't be placed inside the 'V' of another because the oxygen molecule actually would be taking up most of that space. Remind students, if necessary, that they are replicating the model that they had previously created (in Activity One).
- Ask students to imagine now that the water that filled the drinking glass in their model has frozen. Challenge them to alter the model to reflect the change in state. Assure them that the amount of water (the number of molecules, or pieces of wire) in the 'glass' remains the same. Students know that water expands when it becomes ice. Therefore, there would be fewer molecules in the space provided. If it were a real glass filled with water, the ice would be partially sticking out of the glass. Invite the first group that completes its model to draw it on chart paper and describe it to the class. Invite the class to critique the model, recommending alterations, if necessary.
- Students should already know that when a substance changes from liquid to solid, the molecules get closer together. Why, then, would solid water be less dense? It doesn't make sense that water molecules are

further apart in the solid state than in the liquid. As liquid water cools, the molecules move closer together. Moving the molecules further apart to show a model of ice could not be accurate. Just before reaching freezing temperature, something strange must happen to the water molecules themselves.

- Pose the question the students will investigate: What could be happening to the water molecules at the point of freezing? Tell students to return their model to represent cold liquid water. How did they change their model? (moved the molecules very close together) Tell students to imagine the water has solidified to ice. The molecules remain just touching as they were in the liquid state. Now, ask the students to figure out how they can slightly change the shape of the water molecules so that the molecules are still touching each other (which means the water is very cold), but are actually taking up more space. (Students will discover that each molecule can take up more space if the angle is more obtuse, or wider.)
- Tell students that water molecules are closest together at 4^{o}C. Below that temperature, the molecules begin to change shape. When they reach freezing temperature, the angle has increased from 105^{o} to 109^{o}. Ask students if they want to make their model more accurate by using a protractor.
- Debrief the activity:
    - o How did modeling help you to figure out the reason why solid water takes more space than liquid water?
    - o Why does a water molecule in the solid state still have poles even though the shape of the molecule has changed?
    - o Explain why the difference in volume between liquid and solid water that you measured in the previous activity was so small. (the change in angle is slight)

Final Evaluation for Learning Experience Three

Students respond individually to the following statement. The response can be in the form of narrative, detailed drawings, a poem or a song. Teachers can allow groups of students to create and present a skit. However, there should be a preliminary product submitted by each student that reflects the students' ability to meet the criteria for evaluation that are listed below the statement.

Explain why and how hydrogen bonds account for many unique qualities of water that make life possible on Earth.

Criteria:

1. Include an explanation of hydrogen bonding. What is it? Why does it occur between water molecules?
2. Provide at least three different physical properties of water that can be

explained by hydrogen bonding.

3. For each property, give at least one example of how you think this property helps support life.

LE 3 Handout One

Data Chart for Measuring Heat Capacity

Substance Tested: ___________________________

Test Condition: Heating

Elapsed Time (minutes) (X Axis)	Temperature Reading In ^{o}F or ^{o}C (circle F or C) (Y Axis)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Optional experiment:

Test Condition: Cooling

Elapsed Time (minutes) (X Axis)	Temperature Reading In ^{o}F or ^{o}C (circle F or C) (Y Axis)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

LE 3 Handout Two

Exploring a Mysterious Property of Water

Investigation 1: How does water interact when it encounters paper?
Materials: cup of water, paper towel, scissors, ruler

Cut the paper towel into strips of different widths and lengths. Hold the paper upright and dip into the water.

Observations

For group discussion: Why does this happen? How can you explain the behavior of the water?

Investigation 2: How does water behave inside a narrow tube?
Materials: supply of colored water, clear cup, plastic straw, glass tubes of varying diameters, ruler

Place water in the cup. Insert the straw, standing perfectly upright into the water. Observe the column of water. Record your observations. Explore the water's behavior using different amounts of water in the cup.

Repeat using the pieces of glass tubing.

Observations

For group discussion: Why does this happen? How can you explain the behavior of the water? If you used wider or narrower tubes, would the behavior of the water be different? Explain.

Notes to Teachers

- Internet references for descriptions of water geared to middle grades students:

  http://www.oceansonline.com/pages/chemistry/waterproperties.php
  http://www.oceansonline.com/pages/chemistry/water/php
  http://imnh.isu.edu/waterdiscoverybox/SubMenu1/content_chemistry_temp.htm this website has an animated model demonstrating how a water molecule is formed

- More activities on the properties of water:

  http://www.biologylessons.sdsu.edu/ta/classes/lab1/TG.html
  http://www.k12science.org/curriculum/waterproj/waterchemistryactivities.shtml

- The following website contains an extensive web quest created by students:

  http://www.42explore.com/water.htm
  http://imnh.isu.edu/waterdiscoverybox/SubMenu1/content_geography_temp.htm

Part II: Impact of Water on Human Activity

What Do You Already Know about the Impact Water Has on Human Activity?

Overview

Guiding Question: What are the ways that water has an impact on human activity?

The purposes of this learning experience are to introduce the concept that water impacts human activity in many ways. The teacher assesses students' prior knowledge as students engage in a carousel activity to categorize and list all the ways they can think of that they have used water over the past day, and then how water has an influence on human activity.

Evaluation

Students will write a reflective paragraph on why they think that water plays many important roles in the lives of humans.

Materials

- Chart paper
- Broad-tipped and fine-tipped markers
- Tape
- Large post-its

Activity One: How do We Use Water in Our Daily Lives?

- Students work in small groups to make a list of the ways they have used water Last night and today. As they work, pose questions that encourage students to consider the ingredients of products they have used, food and drinks they have consumed.
- Groups take turns calling out one use while the teacher or a student scribes on chart paper or the board.
- Discuss students' observations about the list. Add to the list any uses of water that occurred for the students, such as how water may have been used by someone in preparing dinner, breakfast or a snack for the students.
- Students again work in their group, this time to list the ways water may have been involved in: 1) the preparation of the products and foods that are on the charted list, 2) how the producer makes the

products available to the consumer, and 3) how the manufacturer obtains the products' ingredients.

- Chart the responses. If necessary, pose questions to elicit more information about the less obvious uses of water, such as rain or irrigation to grow crops that they ate, or water used to clean food. Discuss students' observations.
- Ask students to check the products in their kitchen and bathroom, making a list of products that contain water, and to bring the list to the next class.
- Before the next class, have chart paper posted and markers available. As students arrive, ask them to write the products they found at home that contained water.
- Discuss the implications of the list in terms of the importance of water.

Activity Two: What are Some of the Many Ways in which Water has an Impact on Humans?

- Students work in groups to brainstorm all the ways they can think of that water has an impact on or influences humans and human activity. Encourage specific examples, such as: sports events are sometimes rained out, heavy rains can cause flooding, rain is essential for plants to grow that we rely upon (instead of listing a general statement such as, heavy rains can be harmful, or rain is beneficial). Elicit a couple of examples as a class first. Allow each student time to write two or three examples before the groups' brainstorming. Students write each impact on a post-it using a fine-tipped marker. While students are working, the teacher moves from group to group, occasionally posing questions when a group grows silent. Vary the questions from group to group to get a broader range of examples across the class. Examples:
    - Can you think of any specific examples of when water has a <u>harmful</u> impact on humans?
    - Can you think of impacts that are <u>specific to a certain geographical</u> place that people live? Do people who live in the Sahara desert, or the Netherlands, or Greenland have a particular relationship to water that is not experienced by people who live in a different kind of place?
    - Are there <u>indirect</u> impacts? For example, Polar Bears live on ice where they can get into the ocean to obtain food. What would be different for humans if there were no polar ice and therefore no polar bears? What people would be affected? Another example is the ways that climate and weather are affected by water, which have an impact on humans.
    - Are there certain <u>occupations</u> that rely on water?

    - Can you think of any religious practices or spiritual beliefs that involve water?
- Each group designates a person to place the post-its on the board or a wall. These students arrange the post-its into groups. Expect students to continue to move post-its from place to place until the students all can agree on the characteristics of each group. Other students may volunteer to help. Allow one additional student at a time to help. The rest of the students make a note of the possible labels for clusters of post-its as they watch the process. When students have all the post-its either in a group or placed by themselves, the latter being post-its that do not fit within any group, the class agrees on headings. The post-its that are not in a group may suggest potential groups that could have more examples. The teacher or students write the headings over each cluster and individual post-it. Invite students to consider adjustments. Are there groups that are overly broad, that can be subdivided? Are any post-its in the wrong group?
- Arrange a carousel brainstorm: Student volunteers (or the teacher) write the name of each heading at the top of a piece of chart paper. Post charts around the room. Place the post-its that belong to each heading near the top of that chart, leaving plenty of space below the post-its for additional writing.
- Divide students into groups of 3-5. Adjust size of groups so that there is a chart for each group. There may be more charts than there are groups. Assign each group to a chart and provide a broad-tipped marker. Groups designate a recorder. Students brainstorm additional examples within that heading of how water influences humans. Students are given 2-3 minutes (adjust time to meet students' needs but groups should move fairly quickly; the time required may shorten when 2-3 groups have visited a chart and new ideas wane). Instruct students before they begin that they will eventually visit each chart. When the teacher calls change, students move to the next chart (direct students to move either clockwise or counterclockwise). Students first read the additions made by the previous group, and then try to add more examples. The process continues until each group has visited each chart. Allow time at the end for students to revisit each chart and read all the examples that have been added. Students may add more ideas.
- The class debriefs this activity:
    - What do you notice about the listings? Are some longer than others? Why might that be? Are there some listings on a chart that are more important? Which/why?
    - Are there other headings that were overlooked? What are some examples that fall under that heading?

    - Which are there more of, good or harmful? Do you think this is generally true—that water does more good or does more harm to humans? Why do you think this?
    - Look at the listings under the charts. How has this class effort influenced the way you think about water?
- Students each select one of the listings—one way that water impacts humans—and write a paragraph about it: Is it an important impact? Why or why not? Who does it impact, some humans or all? What would life be like for some or all humans if this did not happen?

Investigating the Ways Water Impacts Human Activity

Overview

Guiding Question: Why is it essential to all life on this planet that humans protect all sources of water?

The purpose of this Learning Experience is for students to understand that humans must protect and manage water resources. Students will understand that the supply of fresh water is finite. They discuss the different sources of fresh water (including lakes, rivers, oceans, bays, ground water supplies). Students then discuss the quality of water at each of these sources. Students, individually or with a partner or small group, select a way that water impacts humans and human activity, conduct research on the impact and report their findings to the class in a medium of their choosing, such as a presentation, a newspaper article, a commercial, a song or poem, or a one-act play.

Evaluation

Through information presented to the class in a medium of the students' choosing, students will demonstrate their knowledge of why it is essential that humans protect water in all ways.

Materials

- Access to Media Center
- Access to Internet
- Handout One: Questions to Investigate through Research
- Handout Two: Criteria for Research and Presentation of Findings

Activity: Collecting evidence to support the need for humans to protect all our water sources

- Before class, prepare for student research: 1) make arrangements with the local library and school media center staff, providing the research topics, and 2) schedule the school's computer center and/or arrange for as much Internet access as possible within your classroom.
- Introduce the activity by asking students to summarize what they learned during the previous Learning Experience. Students will now have an opportunity to gain a deeper knowledge of a way in which water impacts human activity and share their findings with the class.

- Distribute Handout One. Each student circles at least three questions of greatest interest. From this list, students select one question to research. Encourage selection of a variety of questions among the students while allowing as much choice as possible. If more than one student selects the same question, ask the students to work together to compile and present the information. In order to ensure all the questions are researched, it may be necessary to ask some students to select a second choice from the three they originally circled.
- Distribute Handout Two and review research criteria with students. Check for understanding. Allow at least two days for research, expecting students to collect some of the information after school either at the school's media center, local library or Internet site, or from a home computer. Review the expectations provided on Handout Two for presenting findings, including the criteria.
- Students conduct their research. Check students' progress, providing guidance and reminding students of the research criteria as necessary.
- Students have one class period to prepare for their class presentation. Criteria are included on Handout Two.
- Students present their findings. Students in the audience record at least two findings from each presentation.
- As a class students discuss the outcomes of the research recording the questions and answers:
    - What did you learn about how water impacts humans that surprised you?
    - What did you learn about for which you are concerned? Why?
    - Why do you think there are organizations across the globe that have as their mission the conservation of water resources?
    - What questions do you now have about water?
- Discuss questions that were raised. If any of the questions lend themselves to research and students are interested in doing the research, form small research groups and allow each group to select a question. Allow at least one day for research and a day for presentations. More than one group may research the same question.
- Other sources for more in-depth discussions and lessons regarding this topic:
  http://msteacher.org/epubs/science/science13/actInvestigating.aspx
   This material is based upon work supported by the National Science Foundation under Grant No. 0424671.

LE 5 Handout One

Questions to Investigate through Research

1. **How does water impact where humans live? Given what you have learned, where would you prefer to live? Why? Where would you definitely not want to live? Why?**

   Getting started:
   Check your knowledge of the different geographical places that people inhabit, such as: coastal community, river valley, desert, an island, near North Pole. Select at least 4 different places. Then look for information about the sources of water that are available in each place; how that water is used to both survive and enjoy life; and hazards related to the water in each of these different places. Remember, water can be frozen, liquid or vapor.

2. **How is water used in various religions? What are some spiritual beliefs that involve water? Why do you think water is so often a part of religious or spiritual beliefs and practices?**

   Getting started:
   http://www.worldwaterday.org/page/442
   Internet search using Boolean search terms: water + mythology of water + religion

3. **How might global warming affect the world's water? What impact would these changes in the earth's water have on humans?**

   Getting started:
   http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2005/11/17/MNG4EFPHK51.DTL&type=science
   http://www.cnn.com/SPECIALS/1997/global.warming/signs/
   http://www.koshland-science-museum.org/exhibitgcc/impacts01.jsp
   http://www.epa.gov/teachers/water.htm

4. **How do bodies of water affect humans who live near them? Consider rivers, lakes, oceans and seas. Given what you learn, where would be an ideal place for humans to create a civilization? Why?**

   Getting started:
   http://regentsprep.org/Regents/global/themes/geography/bow.cfm
   http://www.epa.gov/teachers/water.htm

5. **What are all the ways that water is available on this planet for human use? Also research the flip-side to this question: What are all the ways that humans use water?**

Getting started:
http://www.earthsky.org/faq/amount-water-humans-use-per-year
http://www.unl.edu/agnicpls/impwater.html
http://www.ngwa.org/educator/lessonplans/earthwater.cfm
http://www.epa.gov/teachers/water.htm

6. **In what ways do humans rely on water just for enjoyment? Why do you think these uses of water are important to people?**

Getting started:
If you are using the Internet, use the key words, “enjoying water.” You’ll find a lot of examples.

7. **What are ways that water is involved in politics?**

Getting started:
Search for reasons people fight over water and who is doing the fighting.
http://www.globalpolicy.org/security/natres/waterindex.htm
http://www.waterwebster.com/FloridaAlabamaGeorgia.htm
http://www.worldwaterwars.com/
http://www.epa.gov/teachers/water.htm

8. **What are the ways that water is involved in human health?**

Getting started:
Search for why water is needed to help people stay healthy and what happens if people don’t have a supply of potable (safe to drink) water. Research how water is used in curing or relieving certain health problems.
http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=296
http://quanta-gaia.org/health/Dr.Water.html
http://www.epa.gov/teachers/water.htm

9. **How has water been involved in catastrophes that have impacted humans and other life forms? What can we learn from these catastrophes?**

Getting started:
You may already know of catastrophes that were the result of water, such as Hurricane Katrina, the tsunami that devastated countries in Southeast Asia. Here are some websites for both general and specific examples.
http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20856041~pagePK:64257043~piPK:437376~theSitePK:4607,00.html
http://home.dayton.lib.oh.us/Archives/Flood1913/FloodHistorSketch.html

http://www.iiasa.ac.at/Publications/Documents/IR-99-034.pdf
http://www.epa.gov/teachers/water.htm

LE 5 Handout Two

Criteria for Research and Presentation of Findings

Research

- Use at least 2 sources, (Question #7 must use at least 10 sources). Use any sources, such as books, magazine articles, websites, or an interview with an expert in the area you are studying. Check with your teacher, media specialist, or librarian to be sure the sources you have found are reliable.
- Document each source completely: The documentation should enable others to easily locate the same source.
- Take notes: Obtain enough information to create a presentation of your findings to the class.
- If you are working with others: Each person will have notes to show that you collected information from at least 2 different sources.

Presentation

- Decide on how you will present your findings. Some examples are:
  - -oral report
  - -newspaper article
  - -commercial
  - -cartoon story
  - -song or poem
  - -one-act play
- Students in the class will be able to:
  1. understand the question you researched.
  2. take notes that explain at least two things they have learned.
- If you are working with others:
  1. Each person will have a part in the presentation.
  2. Each person will describe in writing how he/she helped in creating the presentation.

Part III: Impact of Human Activity on Water

Learning Experience Six

What is the Impact of Humans on Water?
Investigating Water Use and Water Quality

Overview

Guiding Question: What is the extent of impact that humans have on the water resources of this planet?

The purpose of this Learning Experience is for students to identify the ways that humans have an impact on our water resources. Students first create a word web that represents the ways they know that humans have an impact on the planet's supply of water. Students read and discuss an article on the issues of water use, then interview a classmate on her reaction to the article. In Activity Three, students work in two teams. One team gathers data on the extent of the problem while the other team finds strategies that their community can use to contribute to the solution, rather than continuing to contribute to the dual problem humans have created of wasting and polluting water. Teams exchange information. The class demonstrates what it has learned by creating a collage to educate local people. Plans are made for finding suitable locations for display.

Evaluation

Students will demonstrate their knowledge of the nature and extent of the problems of water use and quality and ways that they and their local community can contribute to the solution. Each student will prepare at least five problems and five solutions to be integrated with those of classmates to create a collage for display at local sites for which the class members obtain permission.

Materials

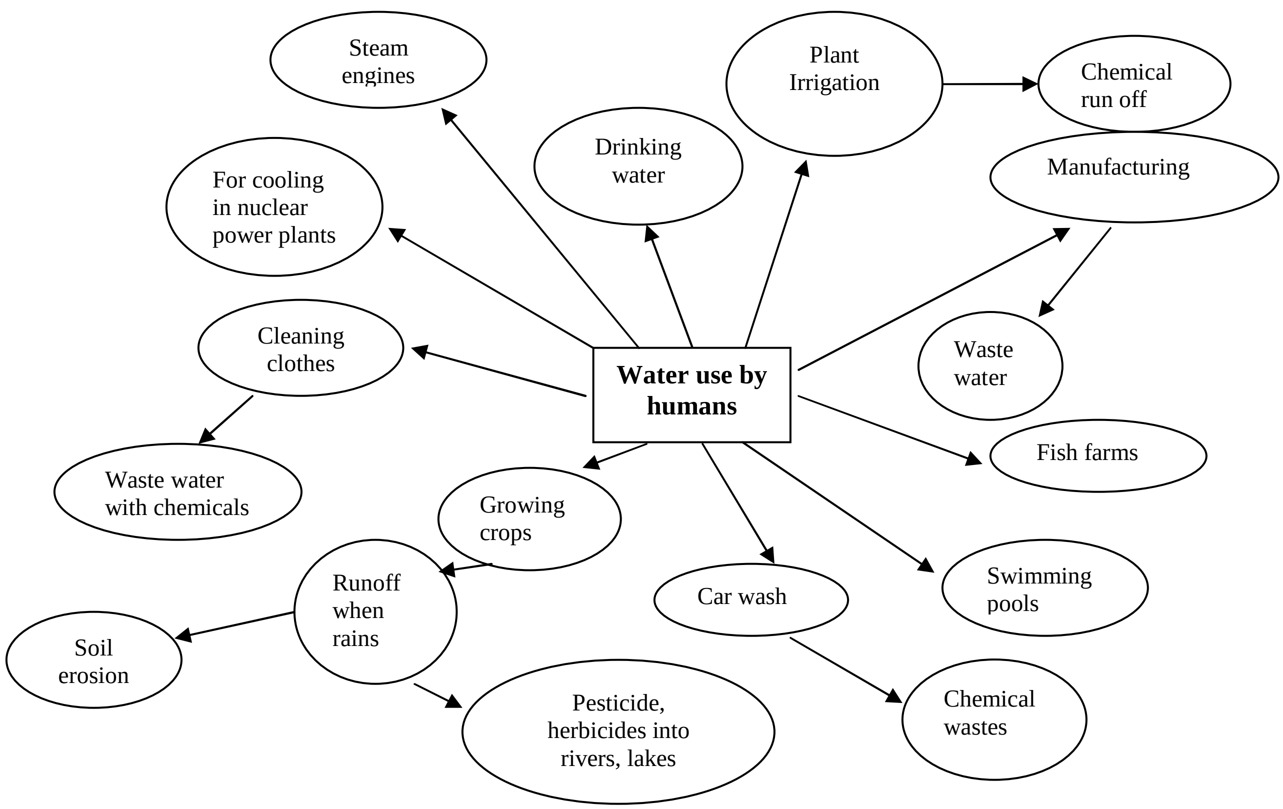
- Handout One: The Water Cycle
- Handout Two: Fundamental Water Issues
- Handout Three:
- Chart paper and markers, tape
- Access to references on the issues of water conservation and water quality, and to the Internet if possible
- Self-standing display board (such as used for science fair projects or at conventions)—as large as possible, for floor or table

Activity One: A Word Web on Issues of Water Supply and Use

- Remind students that most scientists believe that the water we have on this planet now is all the water there has ever been and will ever be on this planet. Display a diagram of the water cycle and ask students to talk with a partner to review how this cycle proves that the amount of water on the planet remains constant. (Depending on what students already know about the water cycle, the teacher may need to revise this activity to provide more instruction.)

  Lesson plans to explain and develop these concepts can be found at the following link:
  http://www.epa.gov/region01/students/teacher/groundw.html

- Ask students to interview another classmate on why he thinks it's important to know that the planet is self-contained, with no loss of water and no input of water into space.
- Students brainstorm all the ways they can think of that humans have an impact on water, i.e., where do humans interfere with, or take advantage of the water cycle? Prompt students to first think of ways that humans use water, then ways that human use of water has an impact on that water. Example of an emergent word web:



- Students interview a partner about the word web. Allow two minutes per student.
    - What do you find interesting, surprising or perhaps even disturbing about the word web?

Activity Two: What are the Basic Water Issues for Humans?

- Before class, review Handout One and Two to identify vocabulary students may be unfamiliar with; prepare student-friendly definitions. Post the definitions. Students read the article in Handout Two, *Fundamental Water Issues.* You may want to create a reading corner for those who would prefer to listen to someone read aloud. Ask students to listen for serious problems about water that are described in the article and make a note of each problem.
- Students form pairs and interview each other on the question. Allow three minutes for each student.
    - What is your personal reaction to the article: What are you feeling? What are you thinking about?
    - What problems did you make a note of?
    - What questions do you have? (Jot these down to discuss later.)
- Place students in groups of 4-5 and designate a recorder and reporter. Students compare their notes and create a combined list of the problems described in the article. Students discuss the following questions and record a summary of their answers.
    - Why do you think the author selected that particular quotation from Martin Luther King, Jr. that appears at the beginning of the article?
    - Do you think the information in the article is reliable? Unbiased? Why or why not? What other opinions could have been presented?
    - If you were the author, are there any other issues you would have included that were not mentioned? If so, what would you have included and why do you think it would have been important for readers to know?
- Groups share some of their discussion points. Also discuss any questions that were raised during the interviews.

Activity Three: Investigating Water Use Problems and Solutions

- Notify the local library and the school media center of the two research topics: 1) the extent of the water problem, and 2) strategies that students and their community can use to contribute to the solution. Obtain access to the Internet (computer center or in the classroom) for one class period for pairs of students.
- Give students the choice of which research team they want to join. One team will gather data on the extent of the water problem. The other team will find strategies that they and their community can use to contribute to the solution. Each team divides into pairs. Allow one class period and the

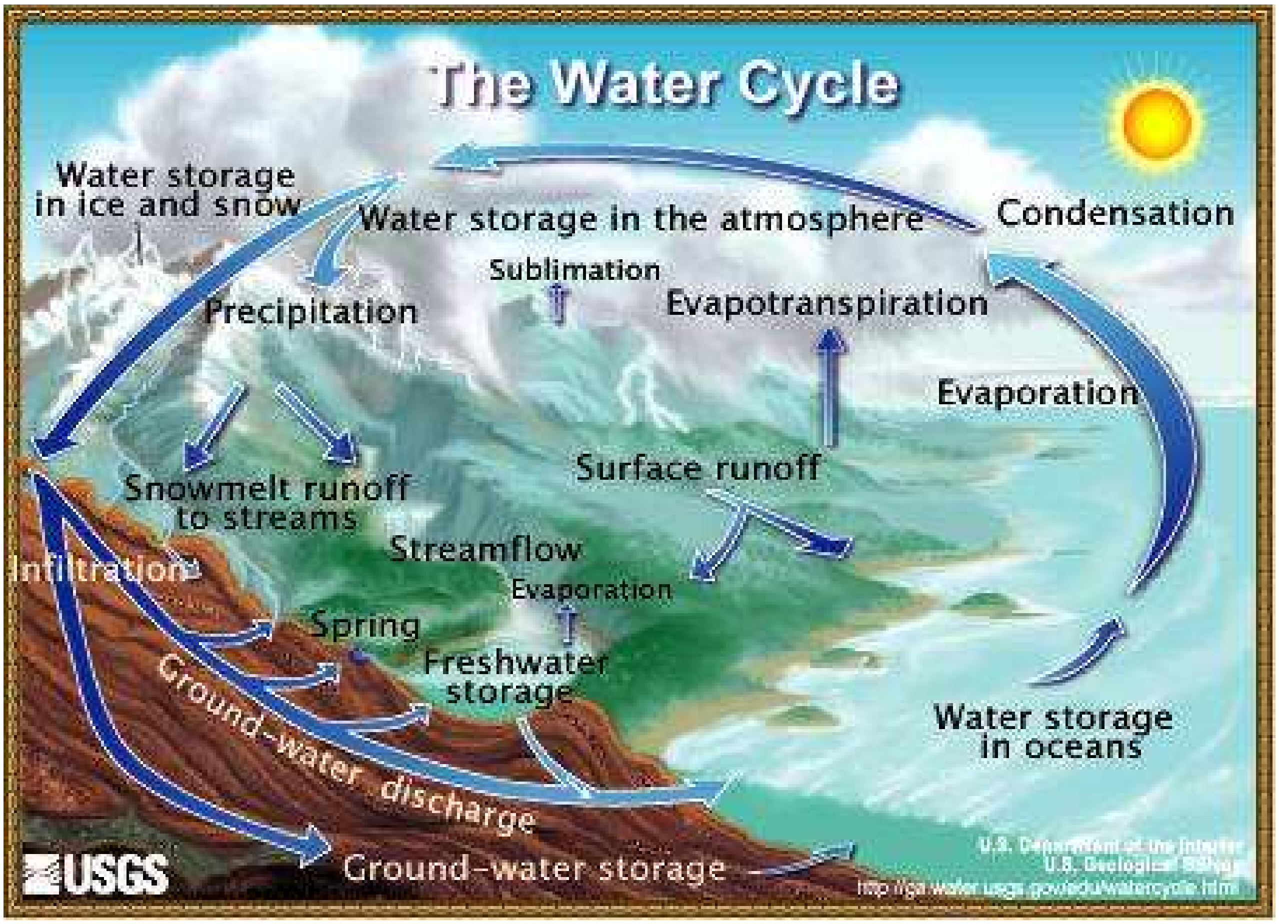
evening to find information on their subject. Students should take notes and document all sources of information. The "Notes to Teachers" at the end of this LE contains additional websites for obtaining information on the problem and on the solution. Print out copies of articles for students who might not have Internet access at home.

- The next time the class meets, arrange the classroom so that the members of each team form a semicircle facing chart paper hanging on a wall. Teams designate a person to lead the discussion, recorder(s) to chart the information and a reporter.
- Teams then report to each other and respond to questions.
- Each student writes a paragraph to the prompt: "Now that I am well informed about water problems and solutions, _____________.

Activity Four: Going Public with the Information

- Students design a display of the information to exhibit in the school and community. Students first generate a list of criteria for the display, such as:
  - People will want to stop and look at it.
  - The information will be understandable to a diverse audience.
  - People will understand what the problems are.
  - People will want to take action.
  - People will leave the display knowing some things they can do.
- Students work in groups to create sketches of possible designs, then vote on which one best meets the criteria. If there are resources and interest, more than one display can be created.
- Tasks for completing the display are assigned according to students' interests.
- Students work in groups of 2-4 to identify a possible exhibit site and make the necessary contacts. Agree on how long the display will remain in each location, create and post a schedule with the locations, dates, names of students to repair any damage after each exhibit, and students who will move the display to the next location.

LE 6 Handout One



From: The United States Geological Survey website
http://ga.water.usgs.gov/edu/watercyclesummary.html

LE 6 Handout Two

Fundamental Water Issues

"Our lives begin to end the day we become silent about things that matter." Martin Luther King Jr.

We, in the West, can be oblivious to some serious global water issues because we're fortunate not to suffer any major water shortages, or experience water supply cut-offs, like many developing world countries are consistently subjected to.

While the world's population is growing steadily, sources of ground and fresh water are not. Cities are increasingly relying on water from nearby rivers. This pumping and diverting of the water is causing major environmental damage and pollution, not to mention the continuous decline of water levels.
We take clean water blissfully for granted, because it's always so abundantly available to us. Unfortunately, this very fact makes us totally oblivious to the daily suffering, hardship and misery of people around the world, living in countries where water is polluted and scarce. Over 3 billion people in the developing world suffer daily from poverty and fatal diseases due to lack of clean water and proper sanitation.
The reality today is that the issue of water is no longer limited to areas of the third world, but is predicted to soon be a major concern for people all over the world.
Climate change due to Global Warming will affect human health and well being through a variety of mechanisms. Climate change can adversely impact the availability of fresh water supplies, and the efficiency of local sewerage systems.
A change in world climate could increase the frequency and severity of extreme weather events. The impact of natural disasters on health is considerable - the number of people killed, injured or made homeless from such causes is increasing alarmingly. Recent tragic events like the Tsunami (Dec 04), the New Orleans disaster (Aug.05) or the massive floods that hit Bolivia in South America (Feb to April 06), Germany and Romania in Europe (Apr. 06) have painfully demonstrated that.

An increase in heatwaves, accompanied by air pollution, is expected be a problem in urban areas, where excess mortality is currently observed during hot weather episodes.

By reducing fresh water supplies, climate change affects sanitation systems and lowers the efficiency of local sewerage systems, leading to an increased concentration of pathogens in water supplies. Changes in rainfall patterns could eventually reduce the availability of drinking water and of water for everyday household needs like washing, cooking and cleaning. Water scarcity may force people to use poor quality sources of fresh water, such as -often contaminated- rivers. All these factors could result in an increased incidence of diarrhea-related and life-threatening waterborne diseases.
Additionally, The growth of private water utility companies in recent years raises fears of us losing control of our most vital resource to a handful of corporations. Analysts predict that within the next 15 years these companies will control 65 to 75 percent of what are now public waterworks. The sad fact is that the privatization of water, -through the installation of pre-paid water meters- is a solution which immediately excludes the world's poor.
It is no wonder that water is a top priority on the international environmental agenda, along with the related problem of climate change.

Amongst the many initiatives to promote awareness of the pressing issues relating to water protection and conservation are the World Health Organization's, as well as the UN's. Others include the Global Water Partnership, the World Water Council, which hosts the World Water Forum, as well as many others NGO's and association like The Fresh Water society, The Groundwater Foundation, World Wildlife Foundation and Water Aid, to name but a few.

The United Nations General Assembly has proclaimed 2005-2015, as the UN International Decade for Action Water for Life starting with World Water Day on March 22nd 2005.

The Water for Life Decade gives the world's goals "a greater focus on water-related issues, while striving to ensure the participation of women in water-related development efforts, and further co-operation at all levels". The 10-year period of 2005-2015 will be critical: the time has come for intensifying advocacy efforts and action on the ground.
The decade (2005-2015) offers an opportunity for revitalizing political commitment, but it also provides a unique chance to launch a provocative worldwide advocacy effort to catalyze greater public participation in the Water For Life global campaign.

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- To catalyze and scale-up the participation of civil society towards building greater societal commitment for the Water for Life effort.

(Goals above are courtesy of the UN's International Decade for Action, Water for Life).

Based on current and emerging priorities, the overall objectives of the UN International Decade for Action Water for Life 2005-2015 are:

- To infuse a sense of urgency and ensure acceleration of effort by all stakeholders in order to meet the 2015 Millennium Development Goals water and sanitation targets.
- To promote greater awareness of the broader picture of how Integrated Water Resources Development and Management critically underpins the efforts to achieve all of the Millennium Development Goals.
- To catalyze and scale-up the participation of civil society towards building greater societal commitment for the Water for Life effort.

(Goals above are courtesy of the UN's International Decade for Action, Water for Life).

"We shall not finally defeat AIDS, tuberculosis, malaria, or any of the other infectious diseases that plague the developing world until we have also won the battle for safe drinking-water, sanitation and basic health care." ***Kofi Annan, Former United Nations Secretary-General***

http://www.pureinsideout.com

Notes to Teacher

Here are some student-friendly websites.

References: The problem

http://www.nrdc.org/water/drinking/uscities/contents.asp

http://www.orcity.org/utility-billing/InterestingWaterFacts.htm

http://www.umich.edu/~gs265/society/waterpollution.htm

http://library.thinkquest.org/C0111401/water_pollution.htm

References: The solution

http://www.nrdc.org/makewaves/makewaves.pdf

http://www.nrdc.org/thisgreenlife/0504.asp

http://www.orcity.org/utility-billing/InterestingWaterFacts.htm

http://www.earth911.org/waterquality/default.asp?beach_id=2077&station_id=3860&cluster=24

http://www.city.ames.ia.us/waterweb/water_plant/ccr-2006.pdf

http://library.thinkquest.org/C0111401/saving_water.htm

Learning Experience Seven

Up Close and Personal:
How Do Each of Us Contribute to the Solution or the Problem? How Can We Each Make a Difference?

Overview

Guiding Question: In what ways can humans, collectively and individually, be responsible stewards of water?

The purpose of this Learning Experience is for students to ascertain the level of knowledge among individuals in the school and/or community regarding the dual issues of water conservation and pollution. Students create a survey and administer it to themselves, and then to their friends, family and neighbors. Students study the results to determine what they can do to help ensure that their local community takes responsibility for conserving water and protecting the quality of water. As the final activity of this module, each student plans and carries out at least one initiative, based on their conclusions regarding the survey results, to improve public understanding of how to be responsible stewards of water.

Evaluation

- Students will gather survey data and interpret what they consider to be important about the results.
- Students will plan and carryout at least one initiative to improve public understanding of how to be responsible stewards of water.

Materials

- Chart paper, markers, tape
- 2-3 examples of surveys
- Computer
- Digital projector

Activity One (Optional): What Does Our Local Public Know About Water Issues and Being a Responsible Steward?

- Refer to "Notes to Teacher" prior to beginning this activity.
- Students debrief the project they have begun using their display to educate local citizens. Is this sufficient? Do we know what our local

citizens know about water problems and the things each of us can do to help solve these problems? How could we find out?

- Students will likely suggest a survey, interviews, and possibly focus groups. The class discusses the options, the pros and cons of each option, then agrees on what strategy the class will use.
- The following steps serve as an example of how to organize the planning. The examples provided here are based on a decision to use a paper survey.
- The teacher presents examples of surveys collected from, for example, newsmagazines, journals, or other class projects to help students envision possible formats.
- The class agrees on a set of criteria to use as a guide for the design. Examples of criteria are:
  - Know who the targeted audience is.
  - Be very clear on what we want to know.
  - Be sure the questions can be understood.
  - Design it so it is as easy as possible to score and interpret the results.
  - Keep it short enough so that people will be willing to participate.
  - Include on the survey a place to document what we think is important to know about the person who has completed the survey (such as, age group, occupation if adult, gender, what level of education was completed).
- Students work in groups to discuss and agree on their responses to these questions:
  - Who is the audience? Why do we want to survey this particular group or these groups?
  - How many people should we survey?
  - What do we want to find out, such as:
    - What do they know about the nature of the water problem?
    - How concerned are they about the problem?
    - What do they know about ways they can help solve the problem?

  The groups write their responses on chart paper.
- The class considers each group's ideas. Where groups have arrived at different responses, such as different target audiences, and cannot come to agreement, the class listens to how each group arrived at its decision and then votes.
- Students form groups to do the first draft on one of these tasks:
  - The questions that will be asked to know something about the individual who is responding to the survey, such as, gender, occupation if adult, as so forth. Consider what might be important to know when the survey results are being studied.

  - Question(s) to ask about one of the things the class decided it wanted to find out, such as, what the person already knows about the nature of the water problem (what is the problem, where is the problem, etc.)

Groups write their drafts on chart paper and present to the class.

- The teacher or a student enters the drafts into a computer connected to a projection device. The entire class can view the text, suggest edits and easily make changes to finalize the survey.
- The class creates a plan for conducting the survey, makes assignments, and establishes a deadline.
- Once the data is collected, students tally the results and enter the data into a chart. A color-coded bar graph can be created. The teacher determines the extent to which the data is analyzed based on the students' level of proficiency in statistical analyses, or whether the school's mathematics curriculum includes this topic at this grade level. In the latter case, this activity would be an ideal cross-disciplinary effort for social studies and mathematics.
- Students interpret and discuss the results.
  - How reliable are the results? Why do we think so? (tings to consider: survey design, wording of the questions, how seriously respondents may have taken the survey)
  - If the results can be trusted as reasonably reliable, what do they tell us about the local public? What kinds of individuals know the most, are the most concerned? Who is least knowledgeable, least concerned? Why do we think this may be so?
  - What action might the class or individuals in the class take that would remedy concerns that are evident from the survey results, such as: Who could benefit from knowing more about the problem and feeling more concerned? Who could benefit from knowing what she or he could do to help be part of the solution? (This leads to Activity Two)
- Discuss as a class what a social scientist would do with the results of her research, why it's important to share research results.
- Students agree on a way to report their results either to a selected audience or to the public.

Activity Two: What Can I do to be Part of the Solution?

- The introduction to this activity will depend on whether students engaged in Activity One. If Activity One was not followed, students can be asked, "Given what you now know about the problem and the solution, what would you like to do to help become part of the solution?"
- Brainstorm possibilities, such as conducting a local awareness or education campaign, involving the entire school community in being

water conservationists within the school (the school becomes a model for water conservation), becoming involved in one of the organizations (local, national or international) that is focused on the problem of conserving water resources.

- To broaden the list of ideas, ask students if they know what other people who are concerned about this problem are doing? The teacher use a computer and digital projector to conduct a web search with students. Some students will likely be very familiar with searching this problem based on Learning Experience Six. Alternatively, students can be paired to conduct web searches, if a computer lab is available. Students would then report their findings.
- Students work in groups to discuss options for action and create a list on chart paper. Groups report their ideas and create a master list for the class.
- Each student selects one action to take. Students may want to work in groups, with a partner, or as an individual. A description of the proposed action is submitted to the teacher for approval.
- The class agrees on the criteria for a high quality action plan.
- Students plan their action using the criteria as a guide, report their plans to the class for any suggestions, make any adjustments, and submit the finalized plans to the teacher for approval.
- Students carryout their plans and present a report to the class on their experience.
- Students debrief this activity in groups:
    - What were the two most important things you learned?
    - Were there any disappointments? Explain.
    - What were the positive outcomes?
    - If you were to do this again, what would you do differently? Why?
    - What questions were raised by doing this project?
- As a conclusion to this module, each student writes a reflection (provide parameters and criteria for evaluation, differentiate expectations as appropriate for your class):
    - Why was this unit of study on water important to me?
    - What have I learned that has made a difference in my life?
    - What, if anything, will I do differently?

Notes to Teacher

Deciding whether to use Activity One:
The focus of the Learning Experience is on involving students in at least one experience of how a responsible citizen approaches community and even world-wide problems. Therefore, Activity One may be omitted if time is limited. However, if the students will not fully engage in assessing the community with regard to the problems related human impacts on water resources, they should at a minimum discuss the value of gathering community data before taking any

action that would be local. It isn't any different from the process teachers undergo to assess students' prior knowledge before planning the learning experiences.

Some benefits of engaging in Activity One:
At a minimum, the students will gain experience in planning, writing, collaborating, and decision making. If taught by an interdisciplinary team of teachers, the acquired learning spans natural science, social science, English/language arts, cultural diversity, and mathematics.

Some caveats on polling:
The accuracy of the results of any data collection strategy, whether survey, interview or focus group, is dependent on good planning. Ideally, whatever has been designed will be trial tested on a small test sample and revisions made as necessary. As ubiquitous as surveys are, and as familiar as students probably are with surveys, students may not appreciate the importance of planning both the format and content of a survey. For example, students should know that questions must be carefully worded so the respondent understands what is being asked, is not in any way influenced by the way the question is asked and is able to give an answer in a format that will provide exactly the kind of data the students want to gather. If the class decides to collect information on the community, the teacher may want to review sources on collecting such data before planning with the class. Two suggested websites, found using key words, 'survey design' or 'survey format' are:
http://www.surveysystem.com/sdesign.htm (a thorough primer)
http://www.ncsu.edu/assessment/presentations/assess_process/survey_research.pdf (This is a PowerPoint presentation.)
http://www.websurveyor.com/pdf/designtips.pdf (easy-to-follow instructions with simple examples on creating good questions)