Temperature: Air vs. Water vs. More Water

Adapted from: "A Change in the Weather?" in Living in Water. National Aquarium in Baltimore, 1997.

Grade Level: basic

Duration: 1 class

Setting: classroom or laboratory

Summary: Students design an experiment to explore temperature changes between air and water and different water volumes.

Objectives: Students will determine if water temperature fluctuates slower than air temperature and if larger volumes of water change differently than smaller volumes.

Related Module Resources:
- "My Stream's Temperature"
- Temperature Info./ Fact Sheet
- HANDBOOK: p. 51-55
- FIELD MANUAL: p. 40-42

Vocabulary: specific heat , heat capacity, thermal stratification

Materials (Included in Module):
- 9 containers with lids: 6 of same size and 3 larger
- 9 thermometers
- aluminum foil

Additional Materials (NOT Included in Module):
- additional containers and lids
- additional thermometers
- access to a refrigerator or ice chest

ACADEMIC STANDARDS (ENVIRONMENT AND ECOLOGY)

7th Grade

4.1.B Understand the role of the watershed.
- Explain factors that affect water quality and flow through a watershed

10th Grade

4.1.C Describe the physical characteristics of a stream and determine the types of organisms found in aquatic environments.
- Describe and explain the physical factors that affect a stream and the organisms living there

ACADEMIC STANDARDS (SCIENCE AND TECHNOLOGY)

7TH Grade

3.2.7.B Apply process knowledge to make and interpret observations.
- Describe relationships by making inferences and predictions
- Communicate, use space/time relationships, define operationally, raise questions, formulate hypotheses, test, and experiment.
- Design controlled experiments, recognize variables, and manipulate variables.
- Interpret data, formulate models, design models, and produce solutions.

3.2.7.C Identify and use the elements of scientific inquiry to solve problems.
- Generate questions about objects, organisms and/or events that can be answered through scientific investigations.
- Evaluate the appropriateness of questions.
- Design an investigation with limited variables to investigate a question.
- Conduct a two-part experiment.
- Judge the significance of experimental information in answering the question.
- Communicate appropriate conclusions from the experiment.

BACKGROUND:

The temperature characteristics of bodies of water directly and indirectly influence aquatic ecosystem processes and the biotic (living) composition and temperature affects other water quality parameters. But various bodies of water are affected differently by increases or decreases of heat sources.

Specific heat (also called specific heat capacity) is the amount of heat required to change the temperature of one unit of mass (1 gram for example) of a substance (like water) by one degree. Specific heat has units of energy per mass per degree. The **heat capacity** is the amount of heat required to change the temperature of *any sized* substance by one degree, and has units of energy per degree. The heat capacity is therefore an extensive variable since a large quantity of matter will have a proportionally large heat capacity. Heat capacity is equal to the product of specific heat of the substance and its mass.

Water has a pretty high specific heat and heat capacity and can absorb more heat than air for each degree of temperature change. No wonder it takes so long to boil a pot of water for your Ramen Noodle snack. In contrast, water cools very slowly and gives off a great deal of heat when it cools.

In nature, bodies of water change temperature more slowly and have more stable temperatures than the air above them. These characteristics have an affect on our weather patterns. Much of our weather is dependent on the fact that lakes and oceans warm adjacent land in winter and cool it in summer. Water can be warmer in Lake Erie than the air temperature in the winter – sometimes making shore areas warmer than inland areas. This also contributes to lake effect precipitation. The opposite is true in the summer. Areas next to large bodies of water can have more cooler climates compared to areas at the same latitude farther inland.

The physical dimensions of the waterway affect the rate at which water will absorb heat and rise in temperature. Shallow water (less volume) will fluctuate in temperature faster than deeper water (more volume). This is because the greater volume of water has a greater heat capacity. Running water tends to be cooler than stagnant, still water. In a stream, the shallow riffles or rapids are often cooler than the slow moving, deep pools. The slower downstream stretches of creeks and rivers (with more volume of water) are often warmer than the faster upstream sections. These downstream sections if deep and slow enough may have a slight **thermal stratification** (temperatures differ at various depths). Warmer surface water floats on more dense, colder bottom water. Freshwater is most dense, or heaviest, at 4°C and this temperature of water is found at the bottom of a lake or river. Water that is warmer or colder than 4°C will always be on top. If it were not for this important characteristic of water, ice would not float on top of water and would instead accumulate at the bottom where aquatic creatures may be trying to live and hibernate.

Human activity may alter the volume of water in waterway, affecting its temperature. Agricultural areas may use a local creek's water for irrigation, especially during warm summer months. If taken in significant amounts, the volume of water in the creek may decrease. When industries and community water authorities withdraw water from a stream, it may also decrease the water depth. Since shallower water heats up more readily than deeper water, water withdrawal may increase stream temperatures.

Because of all of these factors, a large lake such as Lake Erie is definitely affected differently by temperature changes than a small pond. A small creek may change temperature more freely than a large river. This can influence the type of life that exists in these waterways, and the rates at which natural processes like decomposition occur.

OVERVIEW: Students design an experiment to explore temperature changes between air and water and different water volumes. They will do this by using containers of different sizes, some filled with water, and some filled with air. Data will be recorded and a rate of temperature change will be calculated.

PROCEDURE:

Teacher Preparation:

The afternoon before the class when you intend to do this experiment, fill a small and a large container full with cold water. Leave a third container (small) with just air. You can use the tupperware containers in the module. If you need more, any jars or other plastic containers with lids will do, but make sure all of the containers for each replicate are made of the same material – do not mix plastic and glass. Add thermometers to each. Repeat, making as many sets as your class size requires (remember they can work in groups). Put lids on or loosely cover with foil. If the thermometers stick out, allow them to do so through a hole in the lid/foil. Place the jars in a cold location: in a refrigerator, in an ice chest, or outside on a cold, but not freezing, night.

Student Experiment:

1. In class, but prior to bringing out prepared containers, have students design an experiment that they could do in the classroom that would study if temperature changes quicker in air versus water? In a big body of water versus a smaller one? Help the class create a hypothesis and experimental design as needed. You may let them know about the different sized containers available but have them plan what should be done with those containers for the experiment. After the discussion, make sure all students are clear on the experiment design and procedures.

2. Distribute thermometers and data sheets. Have students measure and record the air temperature in the room.

3. Bring out the cold containers and put each group of three containers on lab tables. Keeping lids or foil on, have students record the time and temperature in each container about every five minutes over the next 45 minutes to an hour. They should record their data on the data sheet. Students can be doing other work during this time, as long as they remember to record their data.

4. Have the students make a table showing all of the class data (maybe on a chalkboard). Average the results and record on the data sheet.

5. Have each student make a line graph showing the relationship between temperature and time exposed to the warm air in the room for each size container. Time should go on the horizontal axis and temperature on the vertical. Make sure that different colors or types of lines are used to show each kind of sample. Also make sure there is a key and each axis is clearly labeled (including units). You may also want to insist that the numbers on each axis be marked with appropriate increments and that a dot be used to mark the class average for each time interval.

6. Students can also calculate rates of change for each sample by dividing the total temperature change (difference from start to finish) by the total elapsed time (minutes the experiment ran).

DISCUSSION:

Discuss the results with the students. What was the question the experiment was trying to answer? *How will temperature change vary between air and water and between one* *volume of water vs. larger volume of water.* Which container changed temperature fastest? *Air should have.* Which changed most slowly? *Large volume of water should have.*

Can the students apply what they learned from their experiment to the real world? What would this mean for creatures that live in water? In air? *Generally, animals and plants living in water are subjected to temperature changes that are not as fast or as radical as those that land-living organisms face.*

Have a discussion about the following question: If an animal needs to stay at nearly the same temperature all year, would it prefer to spend the winter and the summer in a big body of water or a little pond? *The bigger the body of water, the less the temperature changes with the season.* Can you make any generalizations about the relative seasonal temperature changes likely to be found in a pond, a lake, or the ocean? *Small ponds show greater changes in temperature with the seasons. Lakes show less and oceans even less. But even oceans, at least at the surface, have seasonal changes.*

What would happen to a creek's water level and temperature if an agricultural area withdrew a significant amount of water to use for irrigation during the summer? *The volume of water in the creek would be reduced. Shallow water (less volume) will fluctuate in temperature faster than deeper water (more volume). The creek's temperature may rise in this situation. Also, shallow areas that were once under water may no longer be under water, affecting aquatic life that may have been living there (plants, mussels, insects).*

EVALUATION:

- Compare temperature changes in air vs water and in bodies of water with different volumes.
- Define specific heat and heat capacity.
- Correctly filled out data sheet and/or appropriate graphs.
- Proper experimental design.

EXTENSIONS AND MODIFICATIONS:

- If students ask why they did not also study large versus small volumes of air, let them repeat the experiment. This time, test the differences in volumes of air.
- Obtain temperature data for a classroom aquarium (unheated) vs. room temperature over a certain time period.
- Have students research how a lake changes temperature through the seasons and what it means when a lake "turns over".
- Have students do academic research on lake effect precipitation or on oceanic/weather events like the periodic El Nino. Have students research these events and their consequences in the library or on the Internet.

NOTES (TEACHERS, PLEASE WRITE ANY SUGGESTIONS YOU HAVE FOR TEACHERS USING THIS ACTIVITY IN THE FUTURE):

Activity Version: November 2001

DATA SHEET: TEMPERATURE: AIR VS. WATER VS. MORE WATER

Name____Date_____________

Temperature readings are in: Fahrenheit_____ Celcius_____ (check one)

Air temperature in room____________

Group Data:

Container	Record temperature under time in minutes since start of measurements												
	0	5	10	15	20	25	30	35	40	45	50	55	60
Small air container													
Small water container													
Large water container													

Rate of change: (divide total temperature change for each sample by the total elapsed time):

Small air container____________________
Small water container__________________
Large water jar__________________

Class Average Data:

Container	Record temperature under time in minutes since start of measurements												
	0	5	10	15	20	25	30	35	40	45	50	55	60
Small air container													
Small water container													
Large water container													

Rate of change (divide total temperature change for each sample by the total elapsed time):

Small air jar____________________
Small water jar__________________
Large water jar__________________

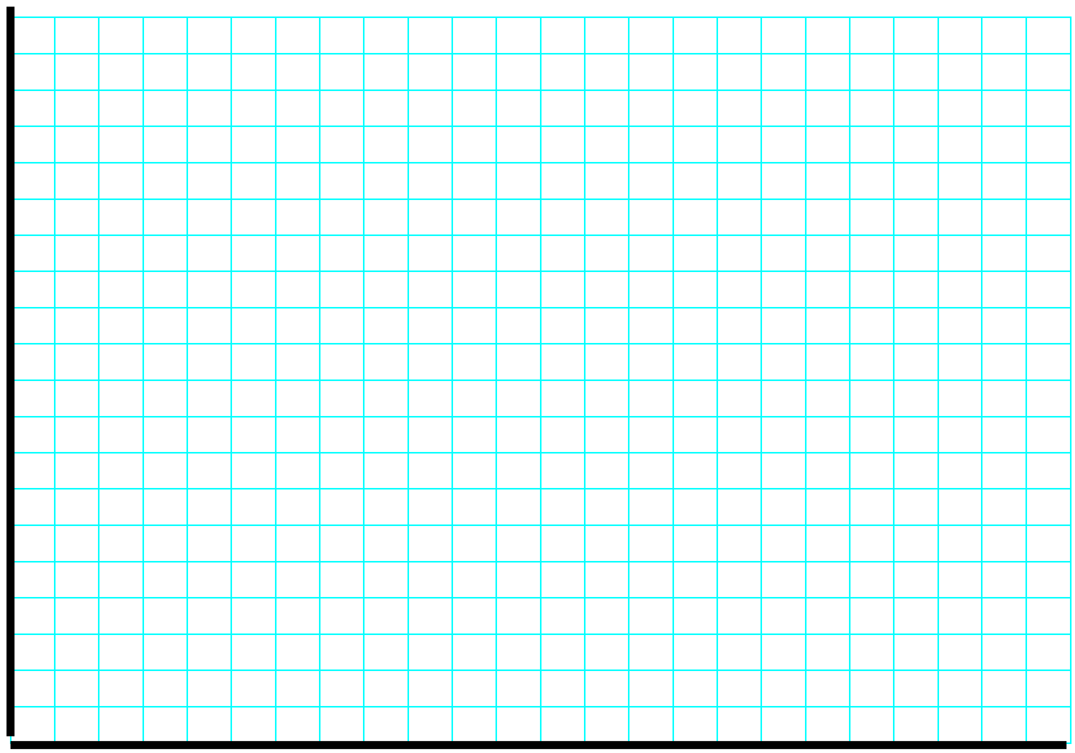
GRAPHS: Temperature: Air vs. Water vs. More Water

**Optional to use, you may want your student to create their own graph.*

Student Name______________________________________ Date_______________

GRAPH TITLE:____

Temp. ^{o}C



Time Elapsed (minutes)