WATER LESSON 3
TEMPERATURE MIXING LAB & MODEL

TEACHER SHEET

Learning Objective: Students will determine how mixing water samples of different temperatures affects the final temperature of a water sample and then apply this to water systems in the environment.

PART 1 Lab Mixing Experiment: The final temperature of two mixed volumes of water of known initial temperatures can be predicted through calculations.

PART 2 Online Mixing Model: Data from Schoolyard Inventory is used in an online model to calculate the runoff volument and predict the runoff temperature of a hypothetical storm.

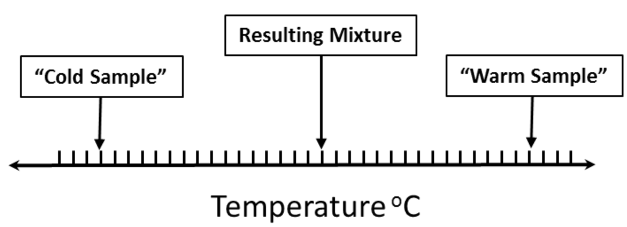
Curriculum Standards:

- NGSS HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity
- NGSS HS-ESS3.C Human Impacts on Earths Systems
- MD E-Lit Standard 1 Topic A: Environmental Issue Investigation
    - Indicator 4: Design and conduct the research
    - Indicator 5: Use data and reference to interpret findings to form conclusions
- MD E-Lit Standard 3 Topic B: Energy Distribution through Earth Systems
    - Indicator 2: Explain that transfer of thermal energy between the atmosphere and the land or oceans produces temperature and density gradients.

Materials Needed:

PART 1: Mixing Lab:

- Styrofoam cups. ~3 per student group
- Thermometers, one per student group.
- Warm and cold water
- Measuring cups/flasks
- Calculator



PART 2: Mixing Model:

- Data from Intro Lesson 3: Initial Schoolyard Inventory
- Access to the Hood-CCWS Runoff Temperature Mixing Model

Introduction: When precipitation comes into contact with objects on the ground that are composed of different materials and/or heated to different temperatures, some of that heat is transferred to the water running off each object's surface. This results in storm water runoff from different sources having different temperatures. However, as the storm water management system on the schoolyard collects water from these various sources, the waters of different temperatures are mixed together and the resulting temperature of the mixed water will be different from any one of the sources.

Possible Discussion:

What information is needed to predict the temperature of runoff resulting from the mixing of waters of various sources?

Students need to realize that both the original temperatures of each runoff source and the volumes of water coming from each runoff source are necessary to predict the water temperature that results from mixing.

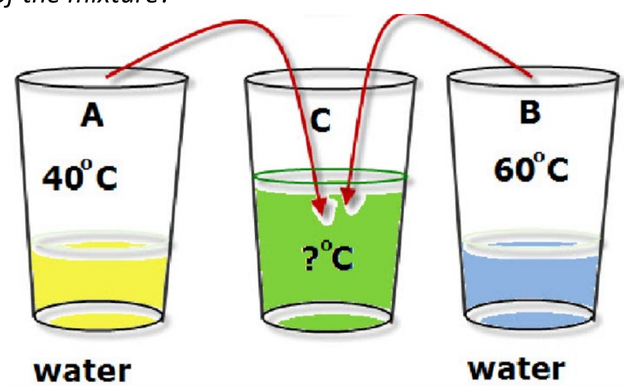
Teacher Background:

Observations from the activity should demonstrate to students that:

1) The colder water will warm up (heat energy "flows" into it). The warmer water will cool down (heat energy "flows" out of it).
2) The whole mixture will wind up at the SAME temperature. (This is very, very important.)
3) The heat energy which "flowed" out (of the warmer water) equals the heat energy which "flowed" in (to the colder water). In symbol form this idea could be expressed as:
$q_{lost} = q_{gain}$, where q is the heat energy lost or gained by the mixing of the water samples.

What relationships between volume and temperature can be seen in these observations? Might it be possible to predict the resulting water temperature of the mixture?

Assumptions:
(mass) (Δt) (Cp) = (mass) (Δt) (Cp)
For Water: volume (ml) = mass (gr)



Moving from Observations to a Quantitative Model and Prediction

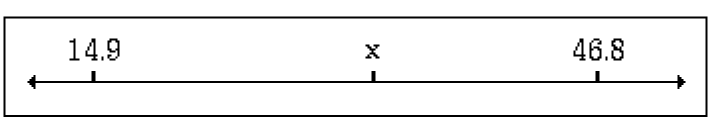
The way in which a resulting temperature can be predicted is best seen by explaining an example.

LAB EXAMPLE: Determine the final temperature when 32.2 g of water at 14.9 °C mixes with 32.2 grams of water at 46.8 °C.

First some discussion, then the solution.

Solution Key Number One: We start by calling the final, ending temperature 'x.' Keep in mind that BOTH water samples will wind up at the temperature we are calling 'x.' Also, make sure you understand that the 'x' we are using IS NOT the Δt, but the FINAL temperature. This is what we are solving for.

The warmer water goes down from to 46.8 to x, so this means its Δt equals 46.8 minus x. The colder water goes up in temperature, so its Δt equals x minus 14.9. This may be a bit confusing, so let's compare it to a number line:



To compute the absolute distance, it's the larger value minus the smaller value, so 46.8 to x is 46.8 minus x and the distance from x to 14.9 is x - 14.9.

These two distances on the number line represent our two Δt values:

a) the Δt of the warmer water is 46.8 minus x

b) the Δt of the cooler water is x minus 14.9

Solution Key Number Two: The heat energy amount going out of the warm water is equal to the heat energy amount going into the cool water. Remember, this means:

$q_{lost} = q_{gain}$ For each heat energy amount: q = (water mass) (Δt) (Cp)

Cp is the "specific heat of liquid water". It is a constant that tells us how much heat energy needs to be lost or gained to change 1 gm of water 1 ^{o}C. It is normally expressed as 4.184 Joules per gm per ^{o}C.

So: (mass) (Δt) (Cp) = (mass) (Δt) (Cp)

With q_{lost} on the left side and q_{gain} on the right side.

Substituting values into the above equation, we then have:

(32.2) (46.8 - x)(4.184) = (32.2) (x - 14.9) (4.184)

Now we solve for x. (Students with a basic algebra background should be able to handle this. However, a quick refresher for these types of problems can be found at: https://www.khanacademy.org/math/in-eighth-grade-math/linear-equations-one-variable/reducing-equations-simpler-form/v/solving-equations-with-the-distributive-property)

The solution:

(32.2) (46.8 - x)(4.184) = (32.2) (x - 14.9) (4.184)

1) On each side of the equation, multiply water mass by specific heat (32.2 X 4.184):

134.7 (46.8 - x) = 134.7 (x - 14.9)

2) To remove the parentheses, multiply 134.7 by each of the terms in parentheses:

6304 – 134.7x = 134.7x – 2007

3) Move the terms containing X to the left side of the equation and all other terms to the right. Then sum the terms on each side of the equation:

- 269.4x = -8311

4) Divide both sides of the equation by -269.4 :

X = 30.9

The resulting temperature is 30.9 ^{o}C!

THIS PAGE INTENTIONALLY LEFT BLANK

The Center for Coastal and Watershed Studies

http://ccwsscience.org

WATER LESSON 3: TEMPERATURE MIXING LAB

STUDENT SHEET

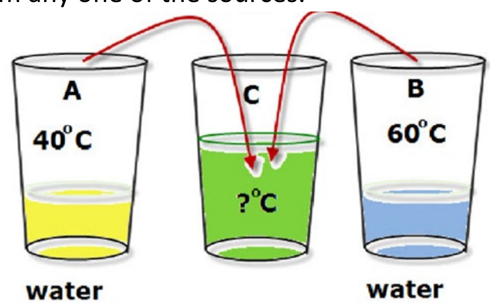
Lab Instructions:

Objective: Students will determine how mixing water samples of different temperatures affects the final temperature of a water sample and then apply this to water systems in the environment.

Introduction: When precipitation comes into contact with objects on the ground that are composed of different materials and/or heated to different temperatures, some of that heat is transferred to the water running off each object's surface. This results in storm water runoff from different sources having different temperatures. However, as the storm water management system on the schoolyard collects water from these various sources, the waters of different temperatures are mixed together and the resulting temperature of the mixed water will be different from any one of the sources.

Materials Needed:

- Styrofoam cups. ~3 per student group
- Thermometers, one per student group.
- Warm and cold water
- Measuring cups/flasks
- Calculator



Equation to use:

$$(Vol_{hot})\ (Temp_{hot} - x) = (Vol_{cold})\ (x - temp_{cold})$$

Vol_{hot}= volume of hot water

Vol_{cold}= volume of cold water

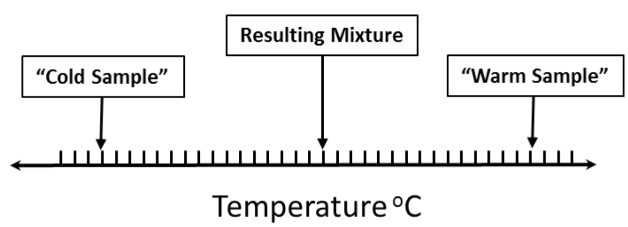
$Temp_{hot}$=Temperature of hot water

$Temp_{cold}$ = Temperature of cold

X = final temperature of mixed water

STUDENT LAB A (Manual Calculations)

Complete the following measurements and record the data and resulting calculations in your lab notebook*. **It is important that you work quickly measuring the temperatures of the water before and after they mixed.***



Part 1: Predict and Measure Temperature Using Equal Volumes of Hot and Cold Water

- Dispense equal volumes of hot and cold water into two of the Styrofoam cups.
- Record volume below.
- Measure and record the temperatures and volumes of two water samples (one cold and one hot).

Volume of hot water (Vol_{hot}) = Temperature of hot water ($Temp_{hot}$) =

Volume of cold water (Vol_{cold}) = Temperature of cold water ($Temp_{cold}$) =

- Using the formula, enter your values and solve for X to predict the final temperature of the mixed water.

$$(Vol_{hot})\ (Temp_{hot} - x) = (Vol_{cold})\ (x - temp_{cold})$$

- Mix the two cups of water together and measure the resulting temperature. Enter the Final Temperature:

- Does your predicted temperature match your actual temperature?

Part 2: Repeat the experiment, completing the calculations using two <u>different</u> volumes of hot and cold temperatures.

- Dispense different volumes of hot and cold water into two of the Styrofoam cups
- Record volumes below.
- Measure and record the temperatures and volumes of two water samples (one cold and one hot).
-

Volume of hot water (Vol_{hot}) = Temperature of hot water ($Temp_{hot}$) =

Volume of cold water (Vol_{cold}) = Temperature of cold water ($Temp_{cold}$) =

- Using the formula, enter your values and solve for X to predict the final temperature of the mixed water.

$$(Vol_{hot})\ (Temp_{hot} - x) = (Vol_{cold})\ (x - temp_{cold})$$

- Mix the two cups of water together and measure the resulting temperature. Enter the Final Temperature:

- Does your predicted temperature match your actual temperature?

THIS PAGE INTENTIONALLY LEFT BLANK

STUDENT LAB B (Use only when two volumes of water are exactly the same)

Theoretical (Calculate the temperature of the mixed water):

1. Use a graduated cylinder and measure 35 ml of cold water and put into a container.
2. Use a graduated cylinder and measure 35 ml of hot water and put into an identical container.
3. Measure & record the two different water temperatures
4. Add the two numbers together.
5. Divide the answer by 2.

Your calculations:

Cooler Temp. ____________

Hotter Temp. ____________

Add the Temps.____________

Divided by 2 _____________

Measure Actual Temperatures of Water:

1. IMMEDIATELY mix the two samples into a third identical container and IMMEDIATELY record temperature.
2. Repeat this process 2 more times

Data:

Actual Water Measurements:

	Trial 1 -	**Trial 2 -**	**Trial 3 –**
Cooler Temp.	__________	____________	___________
Hotter Temp.	__________	____________	___________
Mixed Temp.	___________	____________	___________

Analysis:

1. How close were the actual mixed and theoretical mixed temperatures for each of the trials:

2. Predict the consequence of warm water that: runs off a heated parking lot, drains from a swimming pool, is piped out of a power plant and into a nearby stream that has a cooler temperature.

Part 2: Using the Online Stormwater Runoff Temperature Mixing Model

MODELING A STORM AT YOUR SCHOOL

It's a sweltering summer 90ºF (32.2ºC) day and an afternoon thunderstorm quickly approaches your school. If we know the thunderstorm is going to rain 1" of water on the school, can we calculate runoff volume and predict the temperature of the schoolyard runoff will be to the local stream?

What additional information is needed?

Using the online Hood-CCWS "runoff temperature mixing model", calculate the volume of runoff and predict the runoff temperature from impervious surfaces which are generally the hottest land covers at the schoolyard:

1. **parking lot,**
2. **tennis court, and**
3. **school rooftop.**

Be sure to us the Google Sheet Tab for "Impervious Surfaces Only" for this scenario.

You will need the following data from Lesson 3: Schoolyard inventory:

- Area of school parking lot in acres
- Area of tennis court in acres
- Area of building in acres

>Go to:

https://docs.google.com/spreadsheets/d/1m-qI_4_s9do8uVVxcCpUHV9M_JfnChvgT5BzveEI--Y/edit#gid=1710643182

>Enter the size of your school's impervious surfaces in the correct fields. The temperatures of the runoff from each area is already entered for you.

>Complete the following:

1. What is the # gallons of runoff from the 3 impervious surfaces?:________________

2. What is the predicted temperature of this runoff (ºC)?________________________

3. How does this temperature compare to your streams temperature?

4. How does the runoff temperature compare to your stream's State Use Class temperature standard?

Option: Using the model to include the schoolyard's pervious soils

Use the second tab on the Google sheet to use the model to include pervious soil area on your school grounds. In other words, you'll need the acreage of:

- *Parking lot, school roof, and all the remaining grass (pervious area).*

From Lesson 3: Schoolyard inventory, you will need the following data:

- *Area of school parking lot*
- *Area of building*
- *Total area of grass (pervious) and the general soil type for your area.*

1. What is the # gallons of runoff from the 3 impervious surfaces?:________________
2. What is the predicted temperature of this runoff (^oC)?________________________
3. How has your runoff temperature changed from the first model results?

Use this information in the next lesson, Water Lesson 4.