| | **LESSON PLAN Measuring Transpiration ~ Time to complete 90 minutes (2 45-minute periods)**<br>***prerequisite knowledge for this lab ~ students should be able to draw a best-fit line from a set of data points and be able to determine the slope of a line.** |
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| **Standards** | MS-ESS2-4 Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.<br><br>DCI.ESS2.C The Roles of Water in the Earth's Surface Processes<br>● Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.<br>● Global movements of water and its changes in form are propelled by sunlight and gravity.<br>SEP.ESS2-4<br>● Develop a model to describe unobservable mechanisms.<br><br>CCC.ESS2-4 Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. |
| **Objective** | After this activity, students should be able to:<br>● Explain the rate of transpiration and how it applies to the water cycle.<br>● Calculate the transpiration rate of reaction for a plant species.<br>● Create a graph of collected data and select native plant species based on transpiration data. |
| **Vocabulary** | Absorption: The property of a solid or liquid to attract and hold to its surface a gas, liquid, solute or suspension. A surface-based process while absorption involves the whole volume of the material. |
| **Supplies** | Each group needs:<br><br>● 2 plants of different native plant species, in 4-inch or 1-gallon containers; usually ~$2.50 for a plant in a 4-inch pot and ~$7 for a plant in a 1-gallon pot<br>● (2) 2-liter or 20-ounce plastic bottles, for 1-gallon and 4-inch plants respectively, or (4) produce baggies<br>● (if using produce baggies) 4 twist ties<br>● black permanent marker, such as a Sharpie®<br>● scale, accurate to 0.1 gram, such as a triple beam balance or laboratory scale<br>● 2 stopwatches or timers |

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| | • gallon jug half filled with water<br>• calculators<br>• pencils, colored pencils or markers, ruler (for graphing)<br>• Just Breathe Green worksheet or form (table and graphs to be uploaded separately), one per student<br><br>For the entire class to share:<br><br>• scissors, for teacher to cut plastic bottles<br>• liquid food coloring, for teacher to prepare colored water, 10 drops per group |
| **Bell Ringer** | Transpiration is the focus for the lab activity. What is the importance of transpiration? Which part of the water cycle have you learned about so far is transpiration linked to most often? (Transpiration is important because it is the process by which plants release extra water from their systems, this process is most often linked with evaporation.) |
| **Classwork** | Procedures -<br>**Before the Activity**<br><br>• Gather materials and make copies of the Just Breathe Green Worksheet, one per student.<br>• Acquire at least three different plant species, so that at least two different plants are examined by each group and data on all three species can be collected from other groups for graphing and comparison. For example, horsetail, tickseed and tropical sage, all native Florida plants, were used as examples in the Just Breathe Green Worksheet Example Answers. (It is recommended you look for native plants similar to the ones used in this answer sheet.)<br>• Gather information on each selected native plant species: scientific name, common name and characteristics such as light, water and soil requirements, and height. Alternatively, have students research this information as part of the activity. Usually, state food and agricultural sciences divisions and/or county master gardener programs provide significant native plant data online.<br>• Make sure the main wide part of each plastic bottle is wide enough to fit over the potted plants. Then cut the tops off the plastic bottles where the necks begin to widen, so you essentially have clear plastic domes to cover each plant. Alternatively use plastic produce bags that are big enough to each cover a plant.<br>• Mix up some colored tap water for each team to water its plants. In each one-gallon jug, mix 10 drops of food coloring into one-half gallon of water.<br>• This activity works best conducted outside on a sunny day. Bring materials and plants to an outside area that receives direct sunlight. |

Assign areas for evapotranspiration observation and areas for other experiment work (researching, calculating, graphing, writing).

- Note that students will need their completed worksheets for the last activity in this unit.

**With the Students**

1. Divide the class into groups of two or three students each, depending on the size of the class and resources. Hand out the worksheets.
2. Direct students to record the time of day, temperature, humidity, dew point and weather conditions on their worksheets. Refer to an online weather website that provides localized weather conditions, such as Weather Underground at http://www.wunderground.com.
3. Assign each plant species with a Plant ID #.
4. Water the plants with dyed water until plant media is fully saturated and have students predict what will happen to the dyed water as it moves through the soil and evaporates after transpiration.
5. Have each group select two different plant species to study.
6. Provide students with the plant species' characteristics (or have students research this information) to record on their worksheets.
7. Have students draw an overall sketch of what the plant looks like, providing a detailed drawing of its leaf or grass strand structure.
8. Use a black marker to label one plastic bottle/produce baggie with the plant ID #.
9. Weigh the bottle or bag on the scale and record its weight to the nearest 0.1 gram. (A more precise measurement may be made, depending on the scale.)
10. Place the bottle/bag around the plant. If you are using a produce bag, use a twist tie to secure the bag at the plant base.
11. Set a stopwatch or timer for 10 minutes.
12. When 10 minutes are up, carefully remove the bottle/bag, without letting any of the accumulated water escape.
13. Place plastic bottle/bag on the scale and record its weight on the worksheet.
14. Replace the bottle/bag on the plant and repeat steps 10 through 13; in 20 and 30 minute increments, respectively.
15. Remember to record your observations of the plants and the bottles/bags covering them for 10, 20, and 30 minute increments.
16. Have students sketch overall diagrams of two additional plant species, making sure to include identifying details of the overall plant and its leaf or grass strand structure.
17. Collect transpiration data from students in other groups on the two additional plant species and record it on the worksheets.

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| | 18. Return to the classroom (or use an outdoor classroom) to discuss results and create a data plot. Use different colors or symbols to identify the line for each plant species, and provide a key. Use a ruler to draw a best-fit line of the data.<br>19. Determine the slope of the best-fit lines. To determine the slope of each line, select two points from the best-fit line ($x_1$, $y_1$), ($x_2$, $y_2$) and determine the slope $(y_2-y_1)/(x_2-x_1)$. The slope of the line is the transpiration rate.<br>20. Have students finish their worksheets by answering the questions on the last page.<br>21. Conclude by leading a class discussion to share, compare and review student results and conclusions, as described in the Assessment section. Collect and review the worksheets. |
| **Closing Question** | What is the reaction rate and how does it apply to the water cycle?<br>(Answer: Reaction rates are a critical factor in the design of engineered systems. A reaction rate is how fast or slow a reaction takes place. Within the water cycle, the reaction rate is the speed at which water transfers from one phase to another, for example, from plant uptake to transpiration.)<br>What was the color of the condensed water, why?<br>(Answer: Clear. Only pure water can evaporate. Any pollutants in the water are adsorbed by soil or remain in the plants' organic biomass.) |

Modified Lesson and worksheet from NCWIT.org