

**2008
Winning Lesson Plan
from Glasgow, Kentucky**

*Wee Water Worlds:
Aquatic Biosphere Inquiry*

by Catherina Wiley
Barren County High School

Subject: Biology
Grade Level: 10–12
Duration: Three 90-minute
class periods for setup,
discussion and testing.
One month of independent
observations.

Abstract

In this activity students are to apply their knowledge of respiration and photosynthesis to build a sealed, self-sustaining aquatic ecosphere using common materials. After their initial setup, students will test their design for four days after which they will revise their design (if needed) and seal their ecospheres. Students will then monitor their ecosphere for one month to determine if their design achieved a successful balance between photosynthesis and respiration.

Overview and Purpose

We live on a cellular level, yet these microscope needs are solidly tied to large-scale ecosystem processes. In our world plants, animals and microorganisms rely on each other for matter, nutrients and energy. In this activity students are challenged to create a sealed self-sustaining aquatic biosphere that provides a photosynthesis/respiration equilibrium using common materials. This ecosphere inquiry provides ample opportunities for students to become independent learners and is designed to be congruent with the student's abilities while allowing them to fully experience the concepts and demonstrate their depth of knowledge while meeting the learning goals and is based on the premise that a multi-dimensional real-world context approach will allow for greater recall of material in future applications.

The activity is designed in multiple parts to allow for the observation of various student skills and abilities. They begin the journey with researching ecosphere design and related respiration/photosynthesis factors to establish a strong knowledge base to support their investigation. A class discussion provides an opportunity to reflect on the initial design and self-assess their understanding. While developing their biosphere models students display their ability to acquire and organize materials, implement their design and use appropriate measurement techniques with oxygen probes and data loggers. Students are allowed four days to monitor the structure and function of their organisms to assess the balance between photosynthesis and respiration within their initial design. After this time they must make final adjustments and seal their biospheres. During the next month students are to make regular journal entries regarding their biosphere to record their observations and inferences. The last step is the preparation of a technical lab report in which students must tie together their manipulative and cognitive skills to formulate explanations for their observations. This lab report provides a tangible display of the level of scientific literacy a student has obtained through this inquiry process.

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How Innovative

This biosphere assignment provides a unique design challenge using abiotic and biotic materials gathered from a local creek and pet store. Making the student responsible for the biosphere design and selection of materials provides student with a sense of ownership. The fact that they are responsible for the lives of their wee beasties and the miniature world that contains them is a wonderful source of intrinsic motivation—how often does an assignment turn you into a “god”? Students are forced to view photosynthesis and respiration in a different manner—actual rather than intellectual.

A key component of scientific inquiry is the ability for a student to analyze evidence and data but students often struggle with anomalous data. By the nature of the beast, any inquiry involving living organisms contains unexpected elements such as parasites, reproduction and the resulting overpopulation, mysterious illnesses, etc. These anomalies provide for interesting discussion points where students can share their insights, examine ideas and clarify concepts, allowing individuals to overcome the learning difficulties encountered. This also provides a unique way to discuss bioethics regarding their wee beasties. Any unwanted/uninfected organisms are placed in the class aquarium or are returned to the creek.

The greatest attribute for this assignment is the flexibility it contains. Academically students are required to meet the same standards/expectations, yet the individual methodology allows students to achieve differing degrees of depth and breadth of understanding. This allows them to master the concepts while learning the material at a level commensurate with their abilities. The design of the activity also allows it to be flexible in its execution. For example, it may be assigned to individuals or small groups if it better fits the needs of the learners or the budget. The cumulative lab report rubric is easily adjusted to reflect the individual learning goals of students while the time frame can be adjusted to better fit the class calendar. Specialized probes are not required as the carbon dioxide levels are easily tested using tablets in a standard water testing kit. And because it deals with carbon and oxygen cycling as well as population dynamics, it can be used independently of photosynthesis and respiration units—either within another unit or as a capstone experience for the class.

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Description of Unit

This activity serves as the culminating project for my photosynthesis and respiration unit. We begin the unit by studying the organelles involved in photosynthesis by extracting chlorophyll; performing plant chromatography and use of prepared slides so students have a visual image for these photosynthetic factories. We then study the different reactions and associated factors by placing elodea in varying conditions and measuring the dissolved oxygen in the Pasco photosynthesis tank with our data loggers. Once students have a firm grasp on the principles and processes involved in photosynthesis we turn our attention to the mirror process of respiration. During this portion of the unit we compare respiration rates of germinating peas and discover fermentation through making kimchee. A quick trip to the adjacent creek allows us to measure the respiration rates of minnows, darters, and crayfish we capture at the creek side using the photosynthesis tanks and data loggers (all of which are returned unharmed).

Our classroom discussion begins to focus on the role of the carbon and oxygen cycle in the processes they have observed. It is important for them to make the connections between cellular processes, organisms and inorganic matter through biogeochemical cycling for the upcoming project. Students relate the movement of matter they observed in the various “reservoirs” we tested to sources of energy and associated chemical changes. They must draw upon their experiences with using the probes and labware to determine how/when to test their aquatic biosphere as well as how to collect, organize and analyze the resulting data.

Objectives

The main goals for the unit are reflected in the goals for this inquiry activity. Overall I expect my students to be able to identify the importance of, and shared molecules within the mirror reactions of photosynthesis and respiration. Specifically students should be able to:

1. Discuss how photosynthesis transfers light energy and fixes matter into a usable form and produces oxygen.
2. Identify factors that limit the rate of photosynthesis and address those factors in the design of their ecosphere and explain why the rate of photosynthesis varies under different environmental conditions.
3. Discuss how photosynthesis affects the concentrations of oxygen and carbon dioxide in their ecosphere.
4. Discuss ways to measure respiration in living organisms by relating gas production to respiration rate.

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Educational Standards Addressed

ACT Standards

Interpretation of Data: Determine how the value of one variable changes as the value of another variable changes in complex presentation.

Scientific Investigation: Determine the experimental conditions that would produce specified results; Predict how modifying the design or methods of an experiment will affect results.

Evaluation of Model, Inferences, and Experimental Results: Identify strengths and weaknesses in one or more models; Select a data presentation or a model that supports or contradicts a hypothesis, prediction, or conclusion; Select a complex conclusion that is supported by data presentation or a model; Determine whether given information supports or contradicts a complex hypothesis or conclusion, and why.

Kentucky Core Content

SC-HS-1.1.6: Students will: identify variables that affect reaction rates; predict effects of changes in variables (concentration, temperature, properties of reactants, surface area and catalysts) based on evidence/data from chemical reactions.

SC-HS-1.1.8: Students will: explain the importance of chemical reactions in a real-world context; justify conclusions using evidence/data from chemical reactions.

SC-HS-4.6.1: Students will: explain the relationships and connections between matter, energy, living systems and the physical environment; give examples of conservation of matter and energy.

SC-HS-4.6.4: Students will: describe the components and reservoirs involved in biogeochemical cycles (water, nitrogen, carbon dioxide and oxygen); explain the movement of matter and energy in biogeochemical cycles and related phenomena.

SC-HS-4.6.5: Students will describe and explain the role of carbon-containing molecules and chemical reactions in energy transfer in living systems.

SC-HS-4.6.10: Students will: identify the components and mechanisms of energy stored and released from food molecules (photosynthesis and respiration); apply information to real-world situations.

SC-HS-4.7.1: Students will: analyze relationships and interactions among organisms in ecosystems; predict the effects on other organisms of changes to one or more components of the ecosystem.

SC-HS-4.7.5: Students will: predict the consequences of changes in resources to a population.

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Outside Activities

The personal time that student devote to this project gives the activity intrinsic value, yet does not require so much time as to be intimidating. For the initial homework assignment students are to research aquatic bio- or ecospheres to determine what they are, how they function and the role of organic components. Following their four day test period, students seal and take their ecospheres home to observe for a one month period. During this time they are responsible for making regular journal entries describing their observations and record inferences as to what is occurring in the ecosphere. To ensure that this expectation is being met journals are brought in and checked on a regular basis. The ecospheres will also return at the end to inspect the seals for tampering and for comparison with the final journal entry.

NAME: _____

Ecosphere Inquiry Guide

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Ecospheres or biospheres are small, mostly closed ecosystems containing a mix of plants and animals that meet each other's needs to sustain life. The only input to an ecosphere is energy (light), all other materials are sealed within it and recycled through the process of life, death, and decay. Because it is a closed environment it helps us better understand what impact living organisms and their environments have on each other. You are to build an air-tight (but accessible) aquatic exosphere of your choice that includes autotrophs and heterotrophs. You will monitor the balance of photosynthesis and respiration through the oxygen concentration for 4 days. After this time you will adjust and seal your ecosphere for a one month observation period.

Following the experiment, you are to write an analytical paper describing your design and defend whether or not it successfully balanced photosynthesis and respiration. Include in your discussion the evidence you found for the major reactions, end products, and energy transfers.

Here are some starting points to use while designing your bottle:

<http://www.euronet.nl/users/rkohm/biosphere/>

<http://tech.groups.yahoo.com/group/homemadebiospheres/>

<http://www.open2.net/diyscience/ecosphere/>

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Available Materials

Creek: water, snails, detritus/mud, algae

Store: elodea, ghost shrimp, pea gravel

**You will need to supply a container of your choosing—it must be accessible yet sealable for this project. You are welcome to include other abiotic factors and biotic factors with prior approval.*

Questions to Ponder While Designing Your Ecosphere

- What are the requirements for respiration and photosynthesis to occur and how will these needs be met within the ecosphere?
- Is a really green ecosphere a healthy one? How can the plant/algae growth be controlled?
- How much water should the ecosphere contain?
- How often should I monitor the ecosphere?
- How do molecules and atoms cycle in a biosphere?
- What components/organisms are necessary in the ecosphere to ensure the cycling of nutrients?
- How do environmental factors affect population growth?
- What are other considerations needed to establish homeostasis?