Santa Cruz-Watsonville Inquiry-Based Learning in Environmental Sciences
An NSF GK-12 Project

There's Something in the Water

Investigating water quality in local watersheds

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Field-tested with: the 9th -grade students of Integrated Sciences 1, Watsonville High School, Watsonville, California, Fall 2011.

Concepts: Watershed, water contamination, agricultural runoff, water quality, eutrophication

Skills: Quantitative comparisons, testing hypothesis, using technological equipment, investigating a real world issue

Science Education Standards:

National: A. Science as Inquiry, B. Physical Sciences, C. Life Sciences, D. Earth & Space Sciences, F. Science in Personal & Social Perspectives

California: Chemistry, Biology 6. Ecology, Earth Sciences 7. Biogeochemical Cycles 9. California Geology, Investigation and Experimentation

Module Type: Discussion and lab activity

Duration: One 2-h class and one 30-m class

Key materials (per class):

- Water monitoring kits with dissolved oxygen, nitrate-nitrogen, phosphate, pH tablets, and turbidity stickers (low cost - Flinn Scientific)
- Water samples from local water bodies
- 10 dissecting scopes
- 10 petri dishes
- 10 pipettes
- 10 thermometers
- 50 beakers
- Worksheets (one per person)
- Graph paper (one per person)

Overview: This module teaches students about why watersheds are important components of the ecosystem and how their health can be impacted by human activities. The objectives are to get students to learn what man-made pollutants are entering their local watersheds, predict which water bodies are most impacted by these contaminants, and test their ideas by using kits to measure water quality. Students will learn how jeopardizing the integrity of the watershed impacts both human health and that of the ecosystem and consider potential ways to mitigate these effects.

This project is an opportunity for students to:

- Discover the ecosystem services provided by watersheds
- Recognize how man-made pollutants impact the quality of water, specifically in their communities
- Gain basic skills of experimental design and data analysis to investigate a real life problem

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For more information, see: http://scwibles.ucsc.edu

Background for Teachers

This module will establish an understanding of the components of, importance of, and human impacts on watersheds. Students will first be introduced to the ecosystems services provided by watersheds and the impacts of human activities on watershed health through an introductory lecture and worksheet. The bold words in the following text should be clearly defined for students. In the hands-on portion of this module, students will carry out tests of water quality on samples taken from local water bodies and examine the water through dissecting scopes. Lastly, students will be asked to explain whether or how human activity may have created differences in water quality and consider potential solutions to water pollution.

Science Education Standards Addressed:

This module addresses National Science Education Standards A. Science As Inquiry (p.173-176); B. Physical Sciences (p.176-181), C. Life Sciences (p. 181-187), D. Earth and Space Sciences (p. 187-190), F. Science in Personal and Social Perspectives (p.193-199), as well as the following Science Content Standards for California Public Schools:

Chemistry.

1. Atomic and Molecular Structure: The periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure.

5. Acids and Bases: Acids, bases, and salts are three classes of compounds that form ions in water solutions.

    d. Students know how to use the pH scale to characterize acid and base solutions.

Biology

6. Ecology: Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept:

    b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

    d. Students know how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles through photosynthesis and respiration.

Earth Sciences

7. Biogeochemical Cycles: Each element on Earth moves among reservoirs, which exist in the solid earth, in oceans, in the atmosphere, and within and among organisms as part of biogeochemical cycles.

9. California Geology: The geology of California underlies the state's wealth of natural resources as well as its natural hazards. As a basis for understanding this concept:

c. Students know the importance of water to society, the origins of California's fresh water, and the relationship between supply and need.

Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

d. Formulate explanations by using logic and evidence

What is a watershed?

A **watershed** is a region of land defined by the flow of water as it drains from surrounding peaks to a central location at a lower elevation. It comprises physical components (geology and hydrology) that determine how fast water flows through and over the landscape and seeps into the ground and biotic components (living organisms) that depend on the water to survive. Humans, like all other animals, require water to survive, but we also strongly influence the quality of our watersheds through our activities. Watersheds not only supply our drinking needs, but they are also essential for agricultural, industrial, and environmental processes.

Unfortunately, human activities can greatly alter the physical, chemical, and biological make-up of nearby watersheds, in ways that are detrimental to organisms living there. Mining, construction, landfills, and sewage runoff introduce dirt, minerals, human waste, and other physical contaminants into the watershed. This leads to higher **turbidity**, which is a measurement of the transparency of the water. We can also alter the chemistry of local water bodies by introducing pharmaceuticals through sewage offs, which may interfere with the hormones and development of organisms living in the water. Additionally, agricultural fertilizers, containing large amounts of nitrogen and phosphorous, are washed into water bodies, leading to **eutrophication**. Eutrophication occurs when high levels of nutrients lead to large algae blooms. As these blooms die off, they are decomposed by bacteria, which consume oxygen from the water and essentially suffocate animals, such as fish, living in those waters. Humans can also directly alter the biotic composition of the watershed by introducing foreign plants and animals into the water, which may disrupt food webs and change the structure of the ecological community.

All of these actions erode the quality of the water, which can greatly impact anything living in that watershed. Organisms that rely on clean water for survival will disappear, taking with them ecosystem services such as providing food for people. In many parts of the world, fishes, shellfish, and plants have died from reduced oxygen and light, damaging the livelihoods of local people. The lack of clean water can also increase the risk for water borne diseases in humans and animals. People who drink the water may suffer from increased bacterial and viral infections, as the particles suspended in the water interfere with water disinfection.

What are indicators for water quality?

In this module, students use a kit to conduct five tests for water quality. All students should understand what these tests tell us about water quality and make predictions about what results they expect from different water bodies.

Dissolved Oxygen: As the name suggestions, DO measures the amount of oxygen dissolved in the water. DO is important for plants and fishes and can be depleted through eutrophication. Good quality water has high dissolved oxygen.

Nitrate: Nitrogen is a nutrient important for many organisms and is a major component in fertilizers. This kit tests for nitrogen in the form of nitrate (NO_3). High levels of nitrate may indicate nutrient run-off from land, which can lead to eutrophication. Good quality water has low nitrate concentrations.

Phosphate: Phosphate is also an essential nutrient and one usually found in fertilizers. Like nitrogen, high levels of phosphate also indicate nutrient run-off from land and a potential for eutrophication. Good quality water has low nitrate concentrations

pH: pH measures the acidity or alkalinity of the water. Students should be aware that a pH of 7 is neutral (i.e. drinking water) and some common examples of acidic (lemon, acid rain, battery acid) and basic liquids (sea water, ammonia).

Turbidity: Turbidity measures the cloudiness of the water. Water with high turbidity (cloudy) indicates lots of land disturbances (i.e. construction) that may stir up sediments, which then get washed into water bodies.

Common Student Misconceptions:

Teachers should ensure that students understand how human activities can change water quality and make appropriate predictions. Students should be instructed to make general predictions that are appropriate for the test. For example pH levels should be compared to 7, high DO levels are good for plants and animals, and high levels of the other three tests indicate poorer water quality or more run-offs from land. If water is collected beforehand, explain to the students that there will be no temperature differences since all samples are sitting at room temperature. Lastly, to place this module in a real world context, students should understand that our drinking water comes from local watersheds, and that not everyone has access to filtered tap water and even tap water does not filter or test for chemicals such as pharmaceuticals.

Project Description

Materials: (for a class of up to 40 people)

- 10 Green Low Cost Water Monitoring Kit containing tests (Flinn Scientific) for
    - dissolved oxygen
    - nitrate-nitrogen
    - phosphate
    - pH tablets
    - turbidity
    - http://www.flinnsci.com/store/scripts/prodView.asp?idProduct=15456
- 4 liter water samples from local water bodies
    - Can be obtained from river, lake, wetland, ocean, tap, etc in local watershed
- 10 dissecting scopes
- 10 Petri dishes
- 10 thermometers
- 10 pipettes
- 50 beakers
- Worksheet (one per person)

Preparation

Prior to this module, all students should have been taught about the basic components of watersheds. Teachers should also go and collect 4 liters (or 1 gallon) of water from each water body. Teachers should also prepare the worksheets in advance and set out the necessary equipment (e.g. beakers and dissecting scopes).

Timeline:

1st Day:

30 minutes	Introductory lecture -Go through questions from work sheet -Define words in bold -Intro to lab problem
15 minutes	Hypothesis formation
15 minutes	Collect materials and make observations of water
15 minutes	Carry out first test
15 minutes	Carry out second test
15 minutes	Examine samples under microscope
5 minutes	Clean up
Homework	Students fill out discussion questions

2nd Day:

30 minutes Post lab discussion

Procedure:

1. Introductory lecture

Pass out the introductory worksheet and begin with an interactive presentation (see example in Appendix). Students can follow along with the main points of your presentation by filling out their worksheets. While presenting, make sure to elicit student responses and feedback first before giving them answers to the introductory questions. Be sure to

- Review the components of a watershed and include pictures from your local watershed.
- Discuss at least five services watersheds provide to people and ecosystems.
- Discuss at least five ways people impact the health of watersheds.
- Define eutrophication and explain how it links human activities to watershed health.

Then, explain that the students will be testing the water quality from five different water sources in their own watershed. If possible, show them pictures and a map of the water bodies or, even better, pictures of you collecting the water. Describe the five possible tests that they can perform using the kits and what the results tell us about the health of the water body.

2. Starting Point for Inquiry

Next, divide the class into groups of four students and have each group select two tests to perform. Tell the students to hypothesize about the results of the tests they have chosen for each water body (i.e. whether the tests will indicate high, medium, or low water quality). Make sure students provide a written explanation for their predictions for one of the water bodies.

3. Starting and Guiding Hands-on Activities

1. Ask each group to send one person to collect water from each of the water bodies in the provided 50-ml beakers.

2. All groups should spend five minutes observing and describing each water sample.

3. Have one person from each group retrieve the water testing kit.

4. Every group needs to read the instructions for their chosen tests and explain it to an instructor before they can proceed.

5. Groups carry out their two tests. Make sure to remind students to write down their data.

6. After students complete their two tests, have students take their wetland and lake samples to a dissecting scope to observe the organisms living in the water. Some students may need to refill their samples.

7. About 10 minutes before the class is over, instruct students to begin clean-up.

8. Instruct students to fill out the post-lab discussion questions as homework.

9. In the next class period, spend about 30 minutes discussing student responses to the lab. Here it is important to discuss at least 5 potential solutions that can improve watershed health.

4. Guiding Thoughtful Discussion, Hypothesis-Generation, and Reflection

During the introduction and post-lab discussion, make sure to give students time to answer questions during your presentation. If students do not volunteer answers, try randomly picking names. After students provide responses, ask follow up questions. For example, if a student answers "don't use so much fertilizer," to a question about how to reduce human impacts on watersheds, respond by asking the student to explain how exactly that would help to ensure that he or she truly understands the connections. When discussing the tests students will do, prompt the students by asking questions such as, "Would you expect to find higher or lower phosphate and nitrate levels in rivers near farms? Why?" This will help students when they are trying to make predictions about their own test results.

Assessment Methods:

Class discussions before and after lab activity
Group discussions
Worksheet

Appendices

Glossary

Watershed: A region of land defined by the flow of water as it drains from surrounding peaks to a central location at a lower elevation

Eutrophication: Ecosystem response to high levels of nutrient inputs (nitrogen and phosphorous). Usually manifested as large algae blooms, which consume massive amounts of oxygen after they die off, leading to depleted oxygen levels in the water

Dissolved Oxygen: DO measures the amount of oxygen dissolved in the water. DO is important for plants and fishes and can be depleted through eutrophication

Nitrate: Nitrogen is a nutrient important for many organisms and is a major component in fertilizers

Phosphate: Phosphate is also an essential nutrient and one usually found in fertilizers

pH: pH measures the acidity or alkalinity of the water

Turbidity: Turbidity measures the cloudiness of the water

Reference List

What is a watershed? US EPA's page on watersheds:
http://water.epa.gov/type/watersheds/whatis.cfm