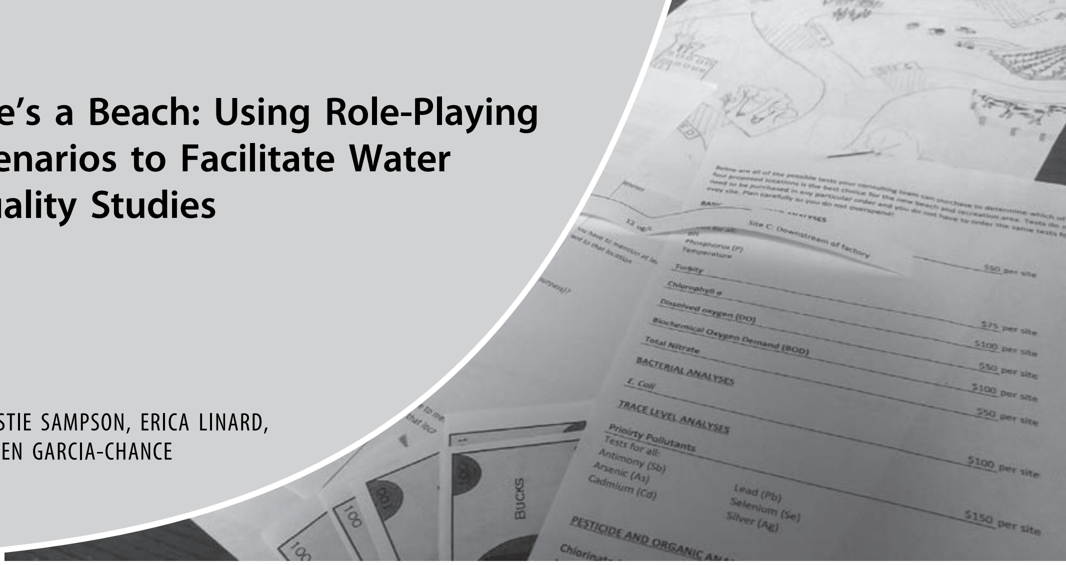
INQUIRY &
INVESTIGATION

Life's a Beach: Using Role-Playing Scenarios to Facilitate Water Quality Studies



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Abstract

Role-playing scenarios in science education offer students an active way to engage in learning as well as to discover how their decisions as citizens, voters, or policymakers can affect environmental and public health. In this activity, students take on the role of environmental consultants, helping city planners decide the best location for a new recreation area located on the fictional community's major waterway. The objective of the game is to engage the students in critical thinking to determine the most relevant water tests needed to accept or reject the four proposed locations, given their knowledge of possible pollutants from different land-use activities. Students work in teams to integrate methods used in determining water quality, such as chemical testing, macroinvertebrate surveys, and bacterial monitoring, into a defendable decision for their recommendation. This activity was designed for and tested by high school students enrolled in AP Environmental Sciences and could be modified for undergraduate ecology or biology courses.

Key Words: *water quality; role-playing; game; consulting.*

○ Introduction

Healthy watersheds contribute to the well-being of both the human and wildlife communities they encompass. The interconnected network of rivers and lakes provide critical resources and habitats throughout our country, yet can be heavily influenced by human activities (IPCC, 2014). Water quality is often determined by measuring both the biotic and abiotic properties within the system, and can be a key consideration when determining where to develop new recreation areas, parks, or protected areas. In this activity, students are able to address these problems while integrating several of the major topics outlined in the Advanced Placement Environmental Sciences guidelines (Table 1).

Students often find it difficult to apply the concepts learned during their biology courses to real-world problems. This results in part from the limited correlations between coursework and practical application, as well as the single-discipline mindset students are often taught in core competency classes. Role-playing exercises can help students to visualize complicated problems and explore the complex, often interdisciplinary, solutions needed to solve them (Bair, 2000). Role-playing games can be used as a tool to facilitate problem-based learning (e.g., Sancho et al., 2009), and allow students to gain hands-on practice and experience failure without the negative consequences of a real-world application (Dieleman & Huisingh, 2006). Problem-based learning has been shown to increase student engagement in classroom activities (Maxwell et al., 2001), promote self-guided learning that leads to developing skills transferable to situations outside of a school setting (Hiebert et al., 1996; Stepien & Gallagher, 1993), and offers a possibly more effective alternative to traditional lecture-based teaching approaches (Mergendoller et al., 2006). The scenario-based game presented in this paper is designed to encourage student exploration into how land-use practices affect water quality and, in turn, wildlife and human health, in a fun and competitive way.

In this scenario, the students are placed into teams (2–4 students), where each team represents an environmental consulting firm. A local city hires the firm to determine the best possible site along a major river for a new recreation area the city is developing. The students receive a map of the four proposed locations in relation to the city and other primary land-use types in the area. The firms must use a set amount of money to purchase water quality test results for each proposed location. Using these results, the firm must either accept or reject each site based on whether sample results fell within acceptable limits for abiotic and biotic variables. However, in addition to ensuring that they choose the correct location and not endanger public health, each team must also consider the cost-benefit ratio of the water quality tests they choose. The set amount of "money" provided to each firm will not allow them to purchase every test at every site without losing money on the project. Therefore, each team must identify possible pollutants or unfavorable conditions at each of the proposed locations, hypothesize which abiotic or biotic factors could be affected, and determine the most appropriate water quality tests to address their hypotheses. The winner of

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Table 1. Relating AP Standards to concepts present in this activity.

AP Standard	Concept present in activity
I. Earth Systems and Resources C. Global Water Resources and Use	Communities need water resources for a variety of applications including agriculture, industry, and household use. Governing officials need to consider the needs of all citizens when allotting public resources.
II. The Living World A. Ecosystem Structure	One way to assess water quality is to look at macroinvertebrate communities in aquatic biomes.
II. The Living World C. Ecosystem Diversity	Wetland and marsh areas may provide ecosystem services to cities, including water purification.
III. Population B. Human Population 3. Impacts of population growth	As human populations grow they require more natural resources, which can contribute to habitat destruction.
IV. Land and Water Use A. Agriculture 1. Feeding a growing population 2. Controlling pests	Increasing amounts of agriculture can lead to deforestation, and can require increased inputs of water for irrigation, pesticides, and fertilizers. Farmers and communities need to evaluate the cost-benefit analyses of chemical use on crops against public and environmental health.
IV. Land and Water Use D. Other Land Use 1. Urban land development 2. Transportation infrastructure 3. Public and federal lands 4. Land conservation options 5. Sustainable land use strategies	Different land use types and policies can have significant consequences for watershed health.
VI. Pollution A. Pollution Types 3. Water pollution	Water pollution can vary in degree and type depending on the source.
VI. Pollution B. Impacts on the Environment and Human Health 1. Hazards to human health 2. Hazardous chemicals in the environment	Water pollution can negatively impact human, animal, and/or plant health.
VI. Pollution C. Impacts	Students decide how to allocate monetary resources depending on which tests will likely produce the results needed to evaluate a site's suitability.

this scenario-based game is the environmental consulting firm that provides the most comprehensive recommendation on why each site is either acceptable or unfit, while spending the least amount of money out of their initial funds. This approach is easily modified to other environmental issues that require researching and weighing different sets of evidence to arrive at the best solution.

Background: Water Quality Analysis

Every inch of solid ground is part of a watershed. All of the water that falls on the earth—be it rain, snow, or even the water you use to wash your car—drains into your area's watershed, which includes all of the streams, rivers, lakes, reservoirs, and even the groundwater flowing into a common outlet. And all of that drainage contains the pollutants the water picks up along the way as it passes through our cities, across our lawns, over our roads, and through our farmlands, moving those pollutants further downstream. Every waterway influenced by the surrounding human activities can face different challenges that, with a little critical thinking, may be predicted by scientists.

The first step a scientist could take is to identify the type of point and nonpoint source pollution that could be entering the waterbody by observing the surrounding land-use types. If a river is in an industrial area, is there a factory or waste treatment plant nearby? Effluent outfalls from these point sources could include solvents or improperly treated sewage. Similarly, nonpoint source pollution can occur in a lake found near a subdivision where high levels of phosphorus and/or nitrogen from fertilizer runoff from people's lawns have entered the waterbody, or in a stream near a cattle farm where runoff from grazing areas may have unsafe levels of harmful bacterium such as *E. coli*.

Using these observations of possible pollution sources, scientists can formulate hypotheses about what type of test will be needed to evaluate water quality in an area. Scientists must consider both the direct and indirect effects of pollutants. For example, run-off from a major highway may cause elevated levels of gasoline byproducts to enter the waterway, directly impacting the survival of plants and animals there. On the other hand, dumping superheated water from a factory cooling operation may not directly endanger local organisms, but can reduce the dissolved oxygen levels in a river, again impacting the aqua life present. Understanding how activities such as agriculture or industry can affect river health in a watershed is an important part of land-use planning (Wang, 2001). During this activity, the students will undertake the role of a scientist working at an environmental consulting firm who must evaluate data at multiple different steps and explain their decision-making process when evaluating how different pollutants associated with different land-use types could affect water quality.

Environmental Consulting Scenario Game

This scenario-based game will require a one-hour class period. It can be integrated into lesson plans exploring water quality analyses and societal impacts, or the instructor can provide the students with Supplemental Materials to review either in a prior class or as a take-home assignment. This activity should be an iterative process, allowing the students to make initial assumptions, evaluate results, modify their views, and repeat until arriving at the correct conclusion. Informational handouts discussing water quality testing methodology and all of the scenario-based game materials below can be found in the Supplemental Materials, though teachers may provide additional materials on their own.

○ Materials

- Map of proposed locations (Figure 1)
- Letter explaining the scenario and the goals of the game
- List of the acceptable limits for water quality test results
- Fee schedule for each water quality test with test descriptions
- Testing results sheets which should be separated into labeled manila envelopes
- Worksheet
- Fake money

○ Activity Preparation

Assemble one packet for each team containing the map of proposed locations, hiring letter, list of the acceptable limits for water quality test results, a fee schedule with test descriptions, a worksheet, and game cash. Compile multiple copies, at least one for each team, of test results into labeled manila envelopes.

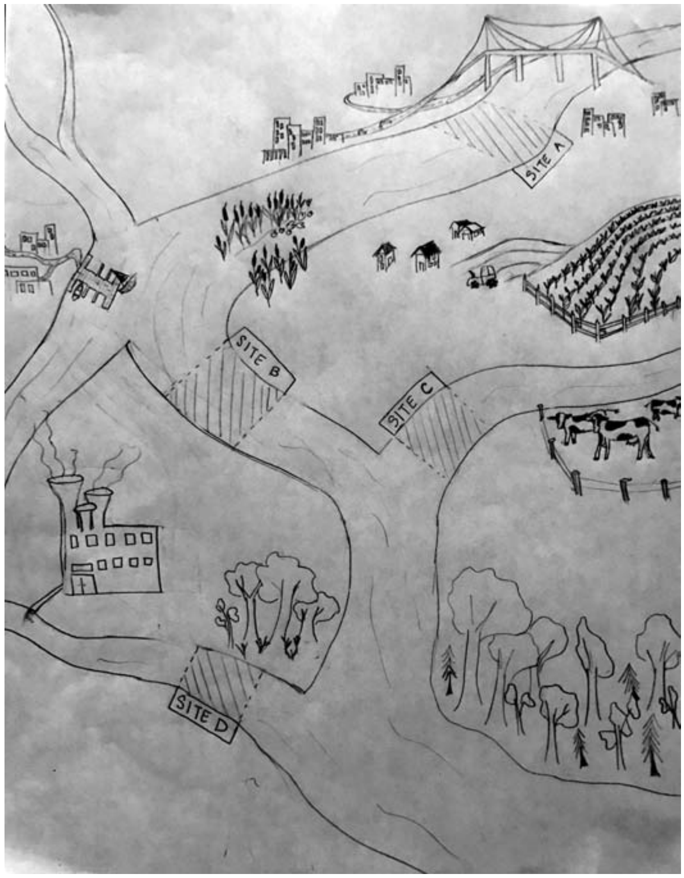

Figure 1. Map of the four proposed locations for the new recreation area.

Procedure

1. Begin the scenario by discussing with the entire class how human activities and land-use types can influence water quality. Encourage the students to think critically about the effects of different land-use methods on watershed health. Which pollutants are found near large cities? What chemicals would you expect to find in your neighborhood stream? What sort of dangers could be found in agricultural run-off?
2. After this quick review, divide students into groups of 2–4 individuals. Give each team one packet containing the scenario information, worksheet, a map, and $4500 in game cash.
3. Allow the students time to review the packet and enclosed materials. Ask the students to develop hypotheses about potential impacts affecting each of the proposed locations and record them on the worksheets provided. Encourage teams to strategically choose the most important water quality tests for each site first.
4. After approximately 10 minutes of discussion within their teams, allow the students to begin purchasing test results from the teacher. The teams do not need to purchase all of the results at once, but should strategically choose a few, review the results, and modify their assumptions and hypotheses. All but one site (in the proposed scenario, this is Site D) has at least one water quality parameter that does not fall within the acceptable limits. The students will continue ordering tests

for the sites until they observe an unacceptable water quality parameter, at which point the site should be eliminated and the students will have to reevaluate the suitability of the remaining locations.

5. Make sure the students state why each site was rejected on the worksheet. After the team members reach a consensus, instruct the students to write a short paragraph detailing why that site is the best location including: what issues they had expected to encounter at the site, what tests they conducted, and the results they reviewed.
6. After all of the teams have finished, have the groups discuss why they chose certain tests (i.e., herbicide testing south of the farmlands), and make sure everyone understands which site is the correct choice.

Assessment

At the end of the activity, the students can submit their worksheets for review.

○ Discussion

Approximately 50 high school students participated in the initial implementation of this activity. Following the activity, a survey was administered using quantitative Likert Scale rankings and qualitative open-ended responses to gauge student's perceptions of the activity. The survey utilized Internal Regulation Board–approved questions (Clemson University IRB #2016-295). Of the 43 respondents, 85.4 percent of students felt the role play activity was engaging. The students overwhelmingly enjoyed participating in the activity and believed it helped to clarify many of the concepts they had been learning in class. For example, one student felt the activity "helped expand my knowledge of the topic."

Students reported that it was important to consider all aspects of a site as "sometimes the most unlikely place will actually have the best water quality. My group didn't even test the water next to the industry because we thought it would have the worst water quality, when, in fact, it didn't." The critical thinking component of the activity and freedom to choose how they would pick a site encouraged students to take a more invested interest in the outcome of the game and increased conversations within the groups. This, in part, along with the small groups and competitive nature of the game, created a sense of comradery where students felt encouraged to speak up in their groups about their thought process and what test results they should purchase next; "it allowed my group to make decisions based on limited information." Further, many of the students expressed excitement in knowing that the game was similar to the process that consulting firms actually use to evaluate water quality for purposes such as building a recreation area or assessing the impacts of certain activities, which seemed to increase the students interest in the process of water quality assessment; "I felt that a lot more goes into city planning that has to do with environmental science or at least it should be this way."

Scenario-based games help students to apply isolated concepts they have learned in the classroom to real-life problems, thinking through all of the resulting consequences of the decisions they make in a realistic setting. These activities help students expand from a single idea—What is water quality?—to integrate concepts across disciplines, develop complex strategies, and assess; "How do different human activities influence water quality and what are the implications for human health and community planning?" The issues that face community planners and scientists often lie at the intersection of multiple fields of study and, because no decision is ever made in a vacuum, can have multiple direct and indirect outcomes for local populations. Many areas want to improve their local economy, but these activities may adversely affect the environmental health of the surrounding area, which in turn can limit recreational activities or even endanger public health. Studies such as Bell and Lederman (2003) demonstrate the importance of developing student understanding of science and its application to their everyday lives and the decision-making process when facing issues as a citizen of the greater community. This activity highlights these objectives, while integrating many of the themes covered by the AP Environmental Sciences exam (Table 1), and enriches student learning.

Modifications

This activity was designed for use in an AP Environmental Science course but can be modified for middle school students or for use in a university setting. Potential opportunities include:

- Ask students to consider discussion points provided in Table 2.
- Simplify the analysis by reducing the number of variables students can assess for each site.
- Ask the students to calculate the EPT index themselves using the macroinvertebrate list and worksheet provided.
- Ask students to integrate environmental policy into their analysis, citing which areas violate applicable state and federal laws.

Table 2. Discussion points to promote in-depth exploration of topics and issues applicable to all of the potential recreation sites.

Site A:	**Below highway, within city**
Issues:	High chlorophyll *a*; high BOD; low DO; high arsenic and lead (priority pollutants); high benzene, tetrachloroethane, toluene, and trichloroethylene (VOCs); fair EPT.
Discussion Points:	Sedimentation caused from increased erosion or "sanding" highways in the winter along with increased nutrients from city sewage can lead to high levels of algae (measured as chlorophyll *a* concentration). Increased bacteria from sewage and storm water run-off increase the biochemical oxygen demand (BOD) and lower the amount of dissolved oxygen. Metal priority pollutants often arise from storm water run-off, because they are used in many industries and in vehicles or can be washed downstream from old or current mining sites. VOCs can enter the water through storm

Table 2 Continued

Site A:	Below highway, within city
	water run-off or by settling into the water system after attaching to dust particles in the air. EPT or macroinvertebrate population may be low due to a number of factors, such as a non-ideal environment due to low dissolved oxygen or due to toxic effects from present pollutants.
Expansion Points:	The persistence of lead (or other legacy contaminants) in the environment from the industrial revolution. Benzene is a government-recognized carcinogen. How would this effect public perception of an incoming recreation area to a site?
Site B:	**Below city and wetland**
Issues:	Elevated benzene.
Discussion Points:	Incoming water from healthy tributaries can improve water quality by increasing dissolved oxygen levels, creating more flow and less sedimentation, and diluting concentrations of pollutants. Wetlands are also natural sequesters of organic material and pollutants; hence the drop in water levels of priority pollutants and VOCs. Benzene, a VOC found in gasoline and exhaust fumes, is still elevated even when a long distance downstream and below the wetlands; boat docks or boating areas upstream could contribute to the elevated levels.
Site C:	**On tributary; below agricultural land**
Issues:	High total nitrates; high *E. coli* count; high DDD and dieldrin concentrations (insecticides); high atrazine (herbicide); high dichloroethylene and trichloroethylene (VOCs); fair EPT.
Discussion Points:	Run-off from farms with fertilizer are high contributors to nitrates and *E. coli* counts. Use of herbicides and insecticides will also result in these compounds getting into the ground water or washing into local water systems. A number of herbicides and insecticides are organochlorines (like the elevated VOCs) and if applied via aerosol could contribute further to the VOC concentration.
Expansion Points:	Nitrates are the limiting component of most ecosystems, and excess amounts can lead to eutrophication and subsequent drop in dissolved oxygen—both issues for macroinvertebrates—and may be something the firm would want to monitor further. What other stressors could exacerbate potential eutrophication issues? (increased temperature with seasons; high BOD).
Site D:	**On tributary; below factory effluent**
Issues:	Slightly elevated water temperatures.
Discussion Points:	Some students' preconceived notion of a factory effluent may cause them to eliminate this site before fully considering it. If so, it is important to remind them that the factory only uses the water as a coolant, and the only effluent is heated river water.
Expansion Points:	How are other water quality parameters affected by temperature? What kind of public perception could there be about a recreation site near a factory? How would you tackle this?

- Discuss possible ways to mitigate or prevent the pollution sources found at each site, or restoration activities the community could undertake to improve water quality at all four locations. What factors could influence water quality that were not included as a variable in this activity?
- Ask the students to research water quality issues in their state and propose ways they would test for public safety issues with regard to water pollution in the affected waterbodies.

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