Artificial Floating Islands

Devarati Bhattacharya, Selcen Guzey, Christina Miller, Tamara Moore

The integrated science, technology, engineering, and math (STEM) unit described in this article focuses on Artificial Floating Islands (AFIs), human- made structures capable of supporting aquatic vegetation on a floating platform. In the last decade, many European countries and the United States have recognized AFIs as a successful tool for longterm habitat restoration (Somodi and Botta- Dukát 2004; Winston et al., 2013). AFIs create near-shore mini ecosystems on a water surface without occupying any shoreline space (see Figure 1). The AFIs consist of floating platforms to support vegetation. The roots of the vegetation growing on the AFI extend into the polluted water body underneath and clean water through the absorption of pollutants. AFIs can move up and down with fluctuating water levels and can be mobile (unanchored) or stationary (anchored) depending on the type of water bodies they serve (see Resources for more information on how AFIs are used).

In this STEM-integration unit based on AFIs, middle school students learn about remediating polluted aquatic ecosystems through measurement and data analysis and then use this knowledge to design prototype AFIs for cleaning up a polluted lake. The unit consists of five lessons (see Figure 2 for an overview) and is designed to take a week; however, a teacher can take up to two weeks if more time is spent on a certain lesson within the unit. These lessons do not have to be conducted successively. The unit is designed to address ecosystem dynamics and water pollution along with science and engineering practices such as defining problems, designing solutions, and understanding stability and change in ecosystems (see Figure 3). Before starting the unit, students need to have some basic knowledge about the relationships between living things, their environment, water resources, and causes and effects of water pollution.

Lesson 1: Setting the context
In the first lesson, students read a fictional newspaper article about a polluted lake (the article we used can be found with the online version of this article at www.nsta.org/middleschool/connections.aspx). Although our lesson is based on a real lake in Minnesota, teachers can focus the entire discussion around a polluted water body that is in close proximity to their school. If the water body accessible to the school is not polluted, it can still be used as a context for the lesson. In that case the AFIs will be framed as a measure to maintain the health of the water body.

The teacher then invites students to share their prior knowledge about point and nonpoint water pollution. Point water pollution comes from a single source (e.g., outlet from a factory) while nonpoint water pollution comes from many diffused sources that do not have a single source of emission (e.g., fertilizers and pesticides used in lawns and gardens and storm water contamination). Students usually share their knowledge of this issue and what they understand to be best practices for lake-pollution prevention, control, and management (e.g., modifying usage of fertilizers and pesticides in yards, taking care of septic systems and not disposing of trash in lakes). After students have shared their ideas, the teacher discusses scientific terms such as turbidity, nitrogen, oxygen, phosphate, and data so that students are able to conceptually understand pollution in water bodies and correlate the scientific terms as well. The teacher also shares ideas about the restoration of water bodies and discusses AFIs as a method for restoration of water bodies (use websites provided in the Resources). In this way, a context is established for the forthcoming engineering challenge.

The teacher then provides students with a newsletter that explains why the polluted lake described in the article needs to be restored (see the newsletter with the online version of this article). After students review the newsletter, the teacher assesses if students were able to understand the problem that the newsletter is presenting (pollution in a particular lake). This can also be another opportunity to review the scientific concepts associated with pollution of water bodies (point and nonpoint water pollution, turbidity, nitrogen, oxygen, phosphate) and biological indicators of the health of a water body(macroinvertebrates).

Lesson 2: Exploring water quality and performing habitat analysis

During this lesson, students visit a lake accessible to them to collect water samples. This is the same lake that the newsletter was based on. Safety note: The water must be free from dangerous microbes and toxins, and students must wear indirectly vented chemical splash goggles and gloves when working with the water and wash their hands afterward. Dispose of the water after use. Be sure to follow all instructions for the storage, use, and disposal of water-testing chemicals and follow all manufacturer instructions.

Students work in groups to collect water samples and run tests to measure water quality by focusing on biotic and abiotic factors. They conduct these tests to understand various water quality parameters. When considering a field trip, it is is important that schoolboard policies and procedures are followed, administrative approval is obtained, bus arrangements (if necessary) are made, and parental consent and student assent are obtained. Students should also be aware of the objective for the field trip and their responsibilitiies. If it is not possible to bring students to a pond or lake, the teacher can collect water samples for students to run water-quality tests in the classroom itself. In the first part of the lesson, students examine the water samples to determine the natural range of factors that indicate the health of water. Water quality is determined by three major parameters:

• Physical measurements of color, clarity, and conductivity of the water
• Chemical analysis (temperature, pH, dissolved oxygen, carbon dioxide, nitrates, phosphates)
• Biological indicators (macroinvertebrates)

Students can use lab probes to complete the chemical analysis and physical measurements of color, clarity, and conductivity. Care should be taken that students follow appropriate safety procedures while using the lab probes and conducting water quality tests in the classroom. Calibrating the conductivity, nitrate, and phosphate probes may be challenging for middle school students, so the teacher should calibrate the probes ahead of time. It is easier to calibrate pH, dissolved oxygen, and carbon dioxide probes (than the nitrate and phosphate probes); most manufacturers provide instructions. Finally, it is critical to collect the water sample as indicated in the instructions for the dissolved-oxygen test you are using. Extreme care should be taken to ensure that the sample is not aerated during collection and air bubbles are not trapped in the container during sampling. If the teacher does not have access to probes, students can collect data on water color, turbidity, temperature, and pH using color charts, a secchi disk, a thermometer, and some pH strips, respectively. If teachers do not have access to a polluted lake, teachers can collect water from any water body accessible to them and students can run the water-quality tests on those water samples.

Furthermore, this lesson is a great opportunity to integrate mathematics, as it is infused with math concepts, mainly in the form of data analysis. While students are analyzing water samples, they can use arithmetic skills to calculate averages, identify trends, and create graphs using their own data collected from their analyses. After students analyze their data, the teacher can ask questions such as “How does the pollution identified through the water-quality indicators affect the lake organisms and humans?” and “Is water quality important to humans and organisms that live at least part of their lives in the water? Why or why not?”

In the second part of this lesson, students perform habitat analysis. Habitat analysis is a process during which students work in groups of three or four to collect data about the habitat surrounding the polluted lake they were focusing on in part one of this lesson. As noted earlier, this is the same lake that the newsletter was based on. (This is the same target lake students are planning to clean up using an AFI, eventually). They establish relationships among animals, plants, and decomposers within the lake ecosystem. The main objectives are to explore the habitat around the lake for which the floating island needs to be designed. An in-depth understanding of the various components of the ecosystem, as well as the interactions among them, helps students envision the floating island as a habitat that supports the same flora and fauna as the lake ecosystem where it is situated. This is essential for the efficient and effective designing of the AFI prototype. If the teacher cannot go on a field trip to the lake, pictures or videos of the chosen water body can be used. The teacher can ask students to identify the communities of organisms shown in the pictures or videos.

Lesson 3: Exploring point and nonpoint pollution

This lesson is helpful in establishing student ownership of point and nonpoint pollution. As noted earlier, point and nonpoint water pollution indicate the source of the pollution of a lake within a watershed. Here we want to emphasize that through changing behavior and practices, individuals can make a difference in water quality. We recommend the use of an EnviroScape model (see Resources). This model is a three-dimensional, self-contained mini-watershed unit that shows nonpoint source pollution and how everyone can contribute in the prevention of environmental contamination. Students can work in groups of three or four to set up their own watershed. They can use readily available products such as cocoa (soil), colored drink mixes (chemicals), and oil to represent point and nonpoint source pollution. Using a water sprinkler to represent rain, storm-water pollution, and runoff become visually apparent. Additionally, students can use materials provided within the model to understand best management practices. The materials, such as felt buffer strips (vegetation) and clay can be used to show conservation and water-pollution prevention measures. This model comes equipped with a user guide, as well as all the materials required for set-up. While this model is easily available to teachers through the local natural resource department, teachers can build their own models by carving a watershed model from Styrofoam (www.iwla.org/index.php?ht=a/ GetDocumentAction/i/2194). Topological features can be added by cutting the Styrofoam and using water glue to attach features that represent factories, farms, and forests. As a final step, the model is sealed with polyurethane or other coatings to make it waterproof.

Lesson 4: Introducing AFIs

In this lesson, students are introduced to AFIs and learn about their design and function. The teacher can provide information about AFIs by giving students an article (see the online version of this article). After reading the article, students discuss the design and functionality of AFIs in the context of the lake being investigated. Students in groups of three or four can also do online research on AFIs and present their findings to the class. Students should search for information regarding the design of AFIs (e.g., purpose, shape, size, buoyancy, durability, and what could be grown on the island).

Lesson 5: Completing the engineering-design challenge

This lesson introduces students to the engineering-design challenge and offers a second opportunity to integrate math concepts by applying relational thinking through measurement. Working in groups of three or four, students plan, create, evaluate, and revise an AFI prototype. In our case, we presented a math-based design challenge and asked students to create an AFI with a perimeter of 66 cm because we have found that this size is relatively easy to build and test. Additionally, students estimate the shape (circle, triangle, square) that would provide the maximum amount of area for plant growth. Students also need to consider the number of plants the floating island can hold, given the information that one plant can be planted every square inch. Finally, students choose materials, select plants, and estimate plant positioning for the construction of the AFI prototype.

Students individually brainstorm possible shapes for their floating island and then share their designs with their teammates. As a team, they choose a prototype shape and start discussing which materials they will use to build their AFI prototype. At this point, teams receive a list of materials and a materials price list, along with the rubric that will be used to score their AFI prototype (see Figures 4 and 5). The goal is to meet all the criteria in the rubric and get a high score.

After teams design and build their AFI prototype, they test it by leaving it in a container filled with water (plastic storage containers or aluminum-foil cooking containers work well) for at least 1 hour and then scoring their AFI on their rubric (testing may be done after school if class periods are shorter than 1 hour). Finally, the groups share their prototype and scores from the rubric with the whole class. After seeing other designs and receiving feedback from classmates, students reevaluate their prototype. The final step in the engineering-design process after students have tested and analyzed their product is to make revisions to improve their design. This allows students to understand the iterative process of an engineering design. Figure 6 shows sample AFI prototypes designed and built by students.

Conclusion

Water quality, water purification, and biological components of an ecosystem make up a large part of the LS2: Ecosystems: Interactions, Energy, and Dynamics disciplinary core idea in A Framework for K–12 Science Education (NRC 2012). While the recent science-education reform efforts call for integrated STEM education, it is still challenging for many science teachers to create effective engineering activities to use in their life-science classrooms. Integrated STEM units such as this one provide an exciting opportunity for teachers to explore the ways in which students learn and apply math and science con- cepts while engaged in an engineering-design challenge. This integrated STEM unit not only incorporates these science ideas, but also emphasizes the scientific and engineering practices dimension ETS1: Engineering Design through the context of an engineering challenge. In this unit, students first enhance their understanding about the diversity and dynamics of ecosystems and then learn how pollution can impact an ecosystem. The engineering challenge, which requires students to design and build a prototype AFI, helps students realize that engineering practices and the use of available resources allow us to solve certain crucial environmental issues. While the activities in this unit allow students to understand that engineering is involved in the application of science, we also believe that the engineering challenge to design an AFI motivates “engineering habits of mind” (NAE and NRC 2009). It allows students to understand how and why science is crucial in developing a product to meet specifications of engineering and vice-versa.

Devarati Bhattacharya (devarati@umn.edu) and Christina Miller are doctoral candidates at the STEM Education Center at the University of Minnesota in St. Paul, Minnesota. Selcen Guzey is an assistant professor of science education at the college of education and Tamara Moore is an associate professor of engineering education at Purdue University West Lafayette, Indiana.