



Bring the River to Your Classroom:

Building and Monitoring Artificial Riparian Ecosystems

TOBIAS KOCHENDERFER, MICHAEL BOGAN , AND JACQUELINE BRUHN 

ABSTRACT

Students that have the opportunity to exercise ownership and choice in their work demonstrate more intrinsic motivation to engage in the learning process. In this article, we present a unit which demonstrates strategies to incorporate this principle into learning about biodiversity and nutrient cycles in the environment. In this unit, students build an aquaponic system using primarily recycled components to house flora indigenous to the riparian regions surrounding the Santa Cruz River. Students generate data from the health of the ecosystem and use mathematical representations of this data to engage in the claim-evidence-reasoning process. This article proposes a sustainable and cost-effective alternative to scientific field experiences which can be expensive and challenging to organize. Additionally, this unit seeks to provide an engaging means to present students with opportunities to collect and interpret data. We present a unit timeline, potential modifications, and supply examples of student work.

Keywords: Riparian ecosystem; biodiversity; data collection; data analysis; data interpretation; data literacy; nutrient cycles; artificial ecosystem

When I first got into scientific research, I recall yearning to pursue my own scientific questions. I had an idealized perception of research: where I would be able to design my own experiments to pursue my own curiosity. In reality, my lack of experience relegated me to working with projects that my supervisors had dreamed up. If lucky, it takes many individuals years to flex the curiosity that likely got them interested in science in the first place. Even at the secondary level, we see this same effect: students have little opportunity to investigate and are consequently bored. “On-the-rails” laboratory activities are excellent at developing scientific skills, but student autonomy is essential to maintain academic motivation. A classroom curriculum that allows for student autonomy and ownership can be key to motivate learners to be excellent data practitioners (Patall et al. 2017). We challenge students to build a controlled ecosystem and monitor its health by collecting data.

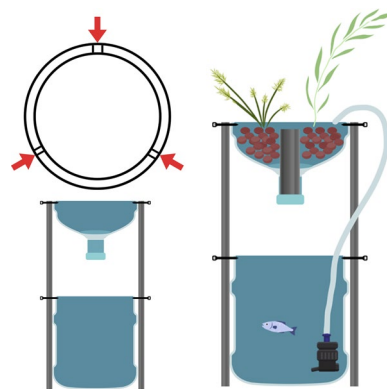
The community of Tucson, Arizona prides itself as one of the longest continuously populated regions of the United States. This continuity could not occur without the Santa Cruz River, an ephemeral stream whose water supports countless species of arthropods, amphibians, birds, mammals and more (Sonoran Institute 2024). With such variety, students that visit would be hard-pressed to leave without finding one thing they were curious about. Our high school is a Title 1 school in the center of Tucson. We have limited access to outdoor spaces and field trips are challenging to coordinate, so we opt to bring the river to our classrooms. Students investigate flora indigenous to the riparian regions surrounding the Santa Cruz River and construct an aquaponic system to house such flora. Students build the system from easily obtainable inexpensive parts such as reused plastic containers and PVC pipes (see materials list on <https://santacruz.arizona.edu/artificial-riparian-ecosystem-unit>). While flora is establishing, students plan and begin carrying out an investigation to monitor the health of the ecosystem. Teachers can modify the time and the intensity of the investigation. Finally, students conclude their monitoring with a discussion of ecosystem health supported by their data. This project allows students to apply NGSS standards involving how physical, chemical, and biological factors impact the biodiversity and nutrient cycles of their controlled ecosystems (LS2-2, -3 and -4, see Kochenderfer 2024 for link to detailed NGSS and Common Core connections). Students use mathematical representations of their data to support claims about factors affecting ecosystem health for a complete claim-evidence-reasoning (CER) process. CER is a framework used to teach students how to make scientific arguments based on data and is integrated into student assessment. The following sections demonstrate the sequential steps necessary to implement this project.

Building low-budget riparian ecosystems (1–2 block sessions)

The building of an artificial ecosystem presents the greatest barrier to entry for most teachers. Fortunately, building these ecosystems can be as inexpensive as \$10 per setup, and may be scaled up if desired. The design that we adapted prioritizes the

FIGURE 1

A simple recirculating contained riparian system can be built from a 5-gallon water jug by cutting it and drilling equidistant pairs of holes (left) and using PVC and “funnel” end joinery (right). Design adapted from Ratnakaran (2014).



use of recycled and low-cost materials. Certain tools are used as part of the building process, such as PVC pipe cutters, and teachers need to demonstrate safe tool use to all students. To see more about the materials that we use, the process that we follow to build (Figure 1), and all supporting lesson materials, please view the lesson page on our website: <https://santacruz.arizona.edu/artificial-riparian-ecosystem-unit>.

Grouping students for the building phase of this project is determined in part by the number of systems being built. The number of systems depends on the materials available for students. If one is using recycled materials to build the ecosystems, the aquarium pump will be the limiting factor because all systems need the pump. If possible, group students in threes for the building phase. I have found that threes are an ideal team size for building while keeping the material cost down. With larger groups, more students are disengaged while few students are actively involved in the building process. However, this may be necessary if one ecosystem per three students is not possible in your classroom. If an instructor opts to have fewer ecosystems to lower the overall cost, students may still work in smaller groups when they are collecting data to maintain student buy-in.

Choosing plants to house (1 class session)

When students build and choose what they will house in their ecosystems, they come to class excited to check in on them and conduct their own studies. This aligns with the concept of self-determination theory, where students that can exercise ownership and choice over their work become more

autonomous, interested, and satisfied learners (Deci and Ryan 1985). To cultivate this self-determination, students choose local riparian plants that interest them as part of an activity that fills one or two 60-minute class periods. Students must have an account on *inaturalist.org* (free community science app where users can upload and share observations of plants and animals) and navigate to the “Explore” tab on the desktop version of the website. In this tab, students are presented with an interactive map where they navigate to a nearby riparian ecosystem. To filter the view to only show species in the plant kingdom, click the “Filter” button and click the leaf icon under “Categories” and view results. During this step of the project, I have heard students argue about whether ash trees or cottonwoods are more beautiful, and exclaim how excited they are to grow a plant from a monotypic genus. Students’ ability and freedom to nerd-out and choose their focal plant species enormously increases their motivation to complete the project.

To ensure that a plant is a native species, click on an observation, then click on the species name. At the top of this page above the image gallery will be a banner that indicates whether the plant is native to the region or introduced (Figure 2).

To ensure that a plant is a riparian species, click on an observation, then click on the species name. Under the image gallery there is a banner with the option “About”. In this section, students may determine whether the species is riparian or not (Figure 3).

Riparian plants will thrive in an aquaponic habitat if they have regular access to circulating water. When collecting specimens to house in the controlled ecosystem, seeds or cuttings may be used depending on the species. At the Santa Cruz River, I have found success collecting seeds from forbs and sedges, such as *Erythranthe guttata* (Sheep monkeyflower) and *Cyperus eragrostis* (Tall flatsedge), and collecting softwood cuttings from trees, such as *Salix gooddingii* (Goodding’s willow) and *Populus fremontii* (Fremont cottonwood). Some plants also may be obtained from seed companies, local seed banks, or native plant nurseries. If wild harvesting, it is essential to practice ethical harvesting and know state laws regarding plant collection.

Planning investigations (1 class session)

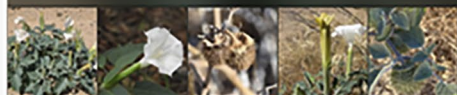
Before students begin planning their investigations, we draw an analogy between human health and ecosystem health. Just as we cannot completely evaluate the health of a human by their optical health, we cannot evaluate the health of an ecosystem just by looking at the pH of its water. Instead, we must take different types of measurement that indicate the overall health of the ecosystem. You may treat these types of measurements as a buffet of options for students depending on the materials that you have available and your curriculum. The following examples vary in complexity of procedure and demand for materials but are all investigations that my students have carried out:

FIGURE 2

Examples of native and introduced plants on the Santa Cruz River in Tucson, Arizona.

Sacred Datura (*Datura wrightii*)

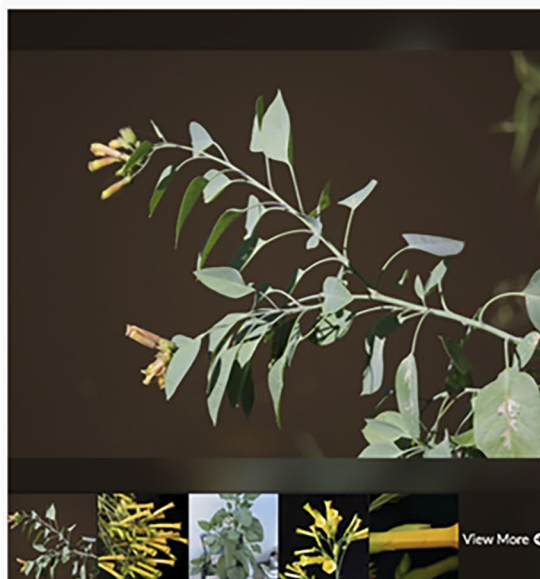
Native to United States (Source List: [/listed_taxa/26299](#))



View More

Tree Tobacco (*Nicotiana glauca*)

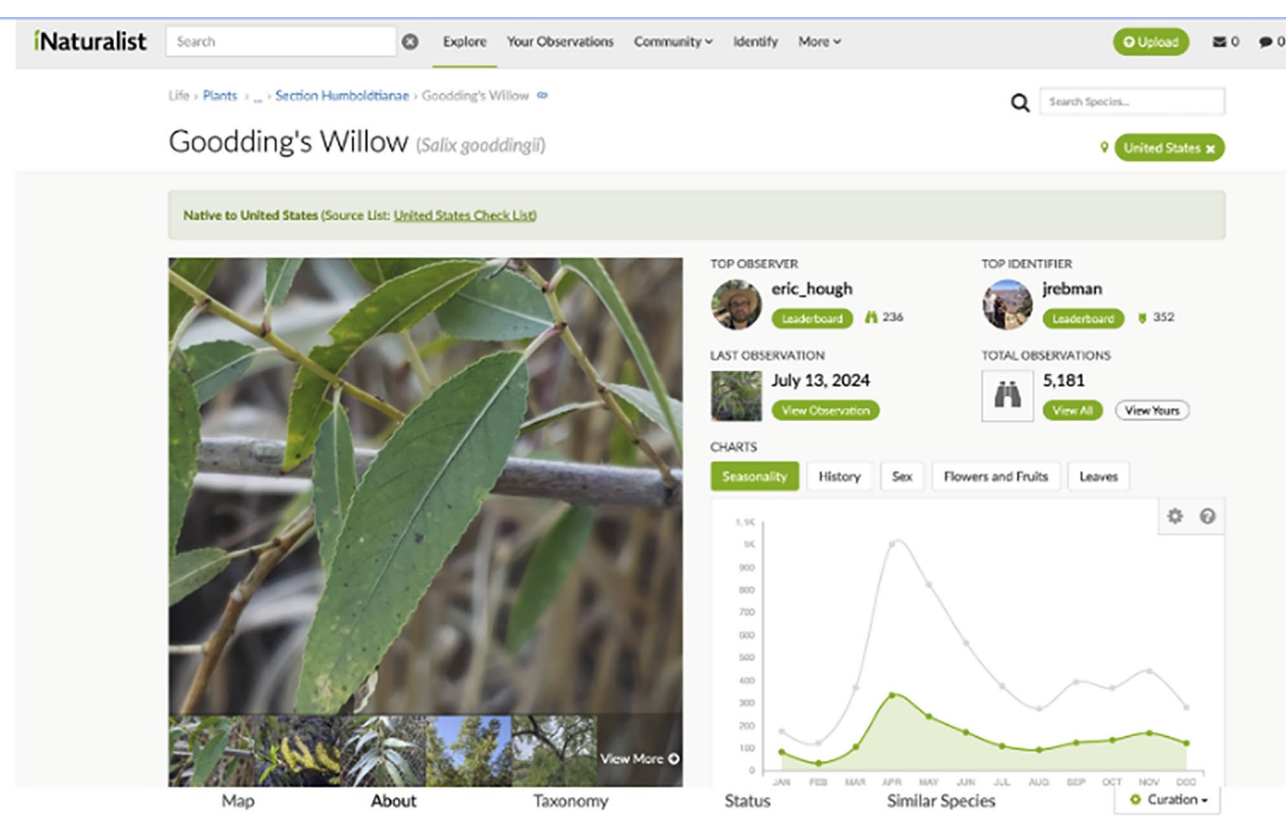
Introduced in United States (Source List: [United States Check List](#))



View More

FIGURE 3

Using iNaturalist to determine if a plant is riparian or not.



Source: Wikipedia

This article relies largely or entirely on a single source. Relevant discussion may be found on the [talk page](#). Please help improve this article by introducing citations to additional sources.

Find sources: "[Salix gooddingii](#)" - news - newspapers - books - scholar - JSTOR (March 2017)

Salix gooddingii is a species of willow known by the common name Goodding's willow, or Goodding's black willow. It was named for its collector, Leslie Newton Goodding.^[2]

Salix gooddingii is native to the southwestern United States and northern Mexico, where it grows in moist and wet habitat in many types of habitat from mountains to desert. It is a common riparian species. It is a tree growing to 3 to 30 m (9.8 to 98.4 ft) tall, with thick, furrowed, shreddy bark and many thin branches. The leaves are up to 13 cm long, generally lance-shaped, and finely serrated along the edges. The young leaves are coated in hairs. The inflorescence is a catkin of flowers up to 8 cm long.

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2. ^a ^b *S. gooddingii* was first described and published in *Botanical Gazette*; Paper of Botanical Notes, 40(5): 376 (-377; t. 12, figs. 1-2). 1905. Crawfordsville, Indiana and Chicago, Illinois. "Plant Name Details for *Salix gooddingii*". IPNI. Retrieved September 4, 2010. "originally written as "gooddingii"; Distribution: Nevada; Collector: L. N. Goodding; Locality: Muddy Creek; ditchy banks (Muddy Creek is a tributary of the Virgin River, which flows into the Colorado in Lincoln County, in extreme southeastern Nevada); Collection Date: 1902-5-2"

External links

- Media related to *Salix gooddingii* at Wikimedia Commons

More Info

	Biodiversity Heritage Library
	BOLD Systems BIN search
	CalPhotos
	California
	eFloras.org
	Flora of North America (beta)
	Global Biodiversity Information Facility (GBIF)
	HOSTS - a Database of the World's Lepidopteran Hostplants
	IPNI (with links to POWO, WFO, and BHL)
	Jepson eFlora
	NatureServe Explorer 2.0
	SEINet Symbiota portals
	Tropicos
	USDA PLANTS database
	World Flora Online

- *Are nutrient cycling bacteria present in our ecosystem? If so, who and how many?*
- *How happy is our plant in a controlled ecosystem? Measuring growth rate and chlorophyll content of leaves.*
- *How do nutrient levels in the water change as our controlled ecosystem develops? Measuring pH, dissolved oxygen, conductivity, ORP, nitrates, ammonium, potassium, and phosphorus.*
- *How do the physical properties of ecosystem water affect plant health? Measuring temperature, turbidity, and color.*
- *If water critters (macroinvertebrates) are introduced into the ecosystems, who survives and what does this say about the quality of the water? Quantifying species via biomonitoring.*

Each ecosystem will have a group of students collecting data on that one unit. Student grouping may be different for the “building” and “collecting” phases of this project depending on a range of classroom factors, but student groups need to be identified before data collection begins. For data collection, I again typically group students in threes, but these groups could be 4 to 5 students. This allows for students to delegate measurement tasks to produce large datasets and become “experts” in their measurement. For example, one student may be tasked with measuring the temperature of their ecosystem while another is tasked with measuring the pH. Each student develops their own protocol for measuring and is responsible for their own dataset that they will eventually combine with other group members. I have observed that this specialization encourages collaboration within groups as they are communicating results. If an instructor is opting for fewer ecosystems than groups, such as 2 data collection groups per system, multiple students may measure the same properties of the ecosystem. This may encourage discussion of conflicting or supporting claims between groups.

Collecting, analyzing, and discussing data (~15 minutes/week + 1 class session for analysis/discussion)

In their projects, students are measuring properties of their ecosystems over time. Allow students approximately 15 minutes a week to collect data and maintain ecosystems. It is important to have equipment for measurement regularly available for students to use. We use the following template for student’s tables (Figure 4).

FIGURE 4

Sample template for a data collection matrix.

Date	[measurement 1]	[measurement 2]	[measurement 3]

When the instructor deems student datasets large enough, they may shift students to the data analysis and discussion process. For this, we present students with local examples of publications that perform environmental monitoring. We use a local nonprofit conservation’s report, called *A Living River* (Sonoran Institute 2024), but you can look for an analogous publication for your local ecoregion using the “Explore the Rivers of the U.S.” portion of American Rivers’ website (American Rivers 2025). Students in my classes investigate *A Living River* reports in pairs and identify what they deem as effective presentations of data. For example, the 2024 edition of the report provides excellent examples for representing vegetation cover, macroinvertebrate diversity, and water flow rates over time (Figure 5).

Once data is visually represented, CER is an excellent framework to approach interpreting results. We regularly practice this process in class so that it is familiar by the time students begin to analyze their own datasets.

Student assessment

Students are assessed throughout the length of this project, with detailed milestones, rubrics, student hand-outs, and assessments available at <https://santacruz.arizona.edu/artificial-riparian-ecosystem-unit>. The following “milestones” are formative assessments that signify progress as students build their ecosystems and collect data: 1) Choosing a plant for your ecosystem, 2) Designing your ecosystem, 3) Planning investigations, 4) Analyzing data. In these four milestones, students are assessed by multiple single point criteria. The rubric has space for teacher feedback and highlights. The intention of these milestones is to ensure that every group of students is prepared to effectively assess the health of their ecosystem in a timely manner. Milestone 1 and 2 serve as a project proposal and should be completed *before* beginning the building phase of the ecosystem unit. Milestone 3 may be completed as or after building is complete but before data collection begins. It is beneficial if Milestone 4 can be completed periodically as students collect data. By doing this, students practice forming scientific arguments and receive feedback multiple times before synthesizing a refined scientific argument at the end of this project.

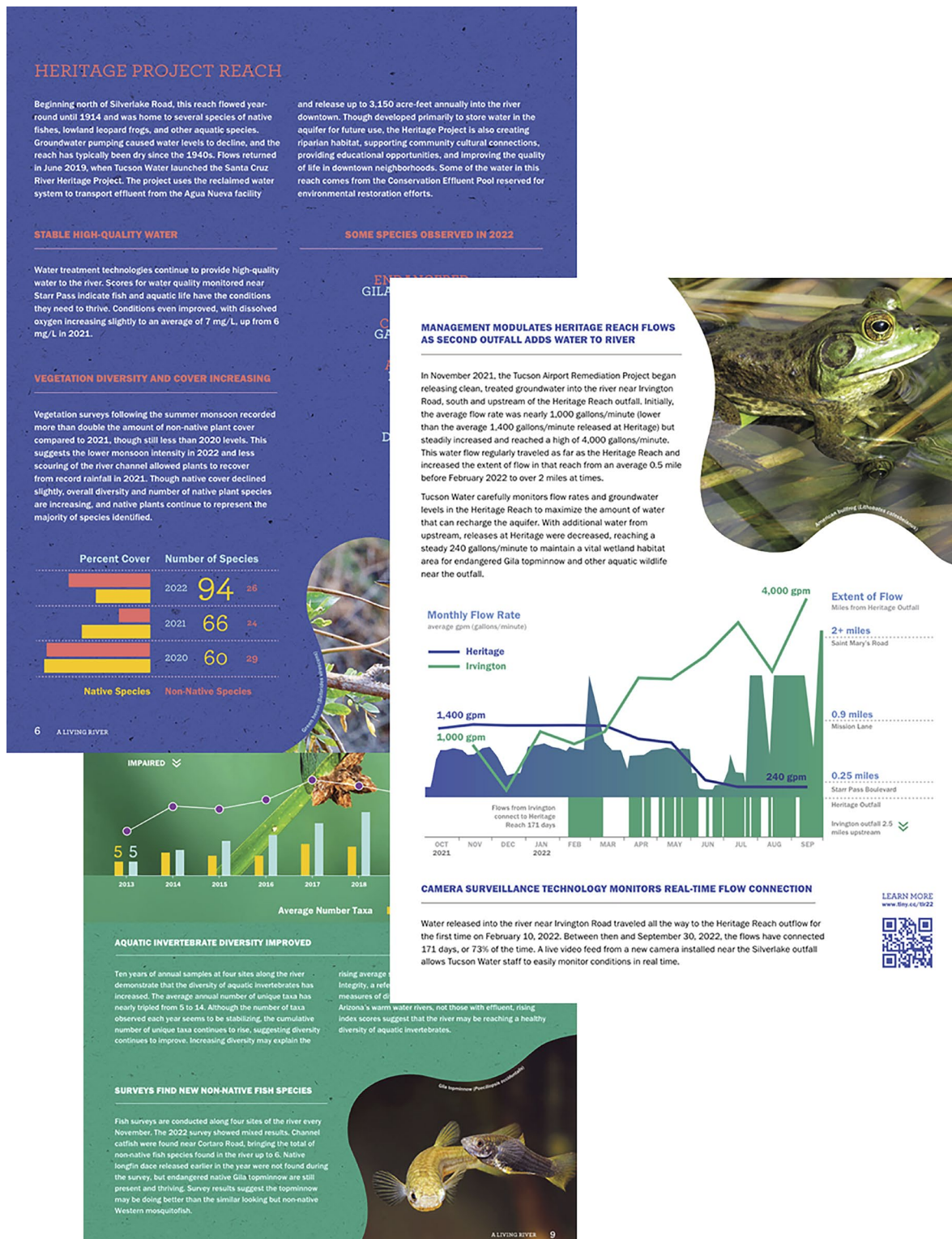
After students have sufficiently collected data and practiced their scientific argumentation, they work on communicating their results in the form of a technical report. In this report, students must qualify the health of their ecosystem, support this claim with evidence, and describe their methodology for collecting evidence. Students are assessed on their ability to present their experiment and findings in a traditional scientific communication. Additionally, students are assessed on their ability to maintain a coherent claim supported by evidence and reasoning throughout their communication (McNeill and Krajcik 2008).

Findings and successes

Once we entered the data collection phase of this project, students would enter the classroom and begin maintaining their tanks and

FIGURE 5

Sample figures from the nonprofit Sonoran Institute's A Living River annual report (2024) about the Santa Cruz River.



collecting data completely unprompted. This high level of engagement shifts discussions with students from *identifying* trends to *evaluating* trends. For example, some students identified that nutrient concentrations were stable over time (Figure 6, *top*). Other students claimed that gastropod abundance in their ecosystem increased over time due to a stable pH (Figure 6, *bottom*). Students experience far less resistance to analyzing data when they have been involved in every step of the design and collection process compared to when I present them with data collected by someone else.

Conclusion

Admittedly this project involves many steps to facilitate. The enrollment in my Plant Science class, where students complete this project, doubled last year and I had to push back this project several times due to insufficient materials for so many students.

However, I was able to address materials limitations by pivoting to using cheaper and smaller 2L soda bottles in place of 5-gallon

water jugs. Even with larger class sizes, once this project is going, it basically runs itself (see Figure 7). My classroom role shifted to more of a learning facilitator. Learning opportunities presented themselves as part of troubleshooting student projects, including figuring out how to house a plant that does not like permanently submerged roots, among other challenges. Despite being a large undertaking, I look forward to running this project as it always brings new challenges and learning opportunities with it.

By bringing the river to the classroom we make riparian ecology and data science more accessible than ever to students. Field-based experiences give students increased connections with their physical spaces and novel ways to practice science. By building controlled ecosystems inspired by these beloved outdoor spaces, students get most of the benefits of field experiences as well as an increased sense of ownership toward the project. As a result, students are motivated to engage in topics of biodiversity and nutrient cycling in a place-based and project-based setting.

FIGURE 6

Examples of student data tables and graphical representation figures.

DATE	PH (PPM)	NITRATE (PPM)	NITRITE (PPM)	COPPER (PPM)	IRON (PPM)
01/26	8.3				
01/29	8.3				
01/31	8.0				
02/02	7.4				
02/05	7.8	50	0	0	0
02/07	7.6	50	0	0.2	0
02/12	8.4	250	1	0	0.3
02/14	7.6	25	0	0.2	0
02/16	7.8	50	0	0	0
02/19	8.4	100	1	0	0.3
02/21	7.8	50	0	0	0
02/26	8.4	250	1	0	0.3
02/28	7.2	25	0	0.2	0
03/01	7.8	50	0	0	0
03/04	8.4	100	1	0	0.3

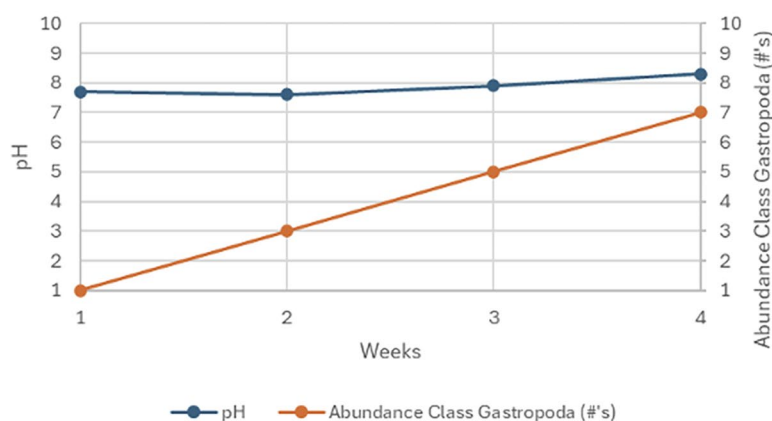


FIGURE 7

Examples of artificial riparian ecosystems created in classrooms at Tucson High School in Tucson, Arizona.



DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

SUPPLEMENTARY MATERIAL

Supplemental data for this article can be accessed online at <https://doi.org/10.1080/00368555.2026.2715372>.

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