SPECIAL SECTION

Teaching Through Water: Science, Community, and Civic Engagement

Water is the most local of global problems, and we all face issues concerning water, from water scarcity to water security, from floods to drought, and from polluted water to remediated wastewater. In Texas, where I live and teach, conversations about water occur every day as our communities tackle the challenges of ongoing drought, protecting our precious aquifers, and the growing need to reuse water sources such as wastewater effluent.

This ongoing wicked problem presents an opportunity for those of us who teach through issues. We can engage with the topic of water and connect the issues we're encountering to the context of a biology, chemistry, or English literature class. I've long used water issues to "CURE" my teaching through classroom-based research involving local ponds, rivers, and wastewater plants. Sanitation and toilet design can spark discourse about pathogen transmission, antimicrobial contamination, and the inequities faced by those who lack access to safe sanitation. When done well, integrated projects and research experiences can generate meaningful data while helping to prepare career-ready students to tackle the concerns of the very communities they come from.

This special section offers a sample of how our educators are integrating water-related issues into their courses. Alexis Denn and Davida Smyth of Texas A&M University-San Antonio show how a partnership between a local wastewater treatment plant and a local high school can lead to data-rich, contextualized case studies. Their work demonstrates not only how nature-based solutions can encourage communities to engage with and embrace these practices, but also how students themselves can become involved in generating the data.

Christine Girtain of the Jersey Shore STEM Ecosystem and Jane Hunt of Ashland University take us from engaging students to engaging teachers. Their paper shows how the "Nourish the Future" national initiative has been developed by teachers for teachers. It takes students on a journey from watershed processes to more complex analyses and investigations, examining human impacts, biological indicators, and chemical testing, and even prompting them to consider remediation plans. Importantly, students are asked what the evidence shows.

Jeena Joseph of Palo Alto College shows that integrating the film Dark Waters into the curriculum can help students engage with complex chemical concepts and the issues surrounding PFAS, the so-called "forever chemicals." Having students create research posters and participate in a short REU experience also affects students' perceptions of and engagement with chemistry.

All of these projects start locally and leverage real data from places that students and their teachers see every day, rather than far-away, hypothetical places they'll likely never visit. They ask students to decide, take responsibility, and do something: write a memo, develop a remediation plan, or advocate for a position. They build partnerships with real-world entities and utilities outside academia. Our authors span K–12, community college, and university settings, moving across the educational landscape. And they all consider issues of equity, access to clean water, who benefits from green infrastructure, and how agricultural advancements impact communities. These projects

epitomize the SENCER ideals by teaching through the issues of water.

Our authors have shown that living laboratories are everywhere around us. They are the local creek or pond, the community garden that our grandparents tend, and the local farmers' market. I hope the work presented in this special section will spark excitement and encourage our readers to find the living laboratories on their campuses and in their communities, and to share what they learn with us in future issues.

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SPECIAL SECTION

TEACHING THROUGH WATER

The Influence of Effluent: A School and Community-Based Course Experience

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Abstract

Nature-based solutions (NBS), such as constructed wetlands, leverage natural processes to address societal challenges, including the return of effluent to communities. Despite scientific support, public acceptance of NBS remains limited, and rural communities are rarely included in conversations. We developed paired case studies grounded in real data, in partnership with a rural wastewater treatment plant. Our goal was to help undergraduate and secondary school students bridge the gap between their knowledge of water reuse and their willingness to adopt it. Infusing case studies with original field data allowed us to advance a genuine research question about the constructed wetland and to immerse the students in an authentic local problem. Our data suggest measurable gains in knowledge, where gains could be made, and a trend towards acceptance of water reuse. This pilot project shows the promise of a course-based case study approach to help build public trust in nature-based solutions in Texas and beyond.

Introduction

Water scarcity poses an increasing but unevenly distributed challenge to communities across Texas and beyond. This issue is further exacerbated by the misuse of these resources and by personal, agricultural, and industrial practices that contaminate our limited supplies and hinder existing conservation efforts (Leijnse et al., 2024; Schumacher, 2025). It is now critical that we diversify our dwindling supplies through the development of alternative water sources, which include treated wastewater effluent. We are increasingly returning treated water to rivers, streams, and aquifers that serve as freshwater sources for surrounding communities (Texas Water Development Board, n.d.). One method for remediating this treated wastewater is to create artificial wetlands at the point of release into freshwater bodies, as is being done in rivers, at the City of Castroville WWTP (Ayaz, 2008) and elsewhere. While each of these methods of recycling treated water has substantial merits, each one also provides a pathway for biological and pharmaceutical micropollutants to cycle back into these communities. Despite potential consequences and the lack of studies on this topic, the reuse of treated non-potable effluent is one of the most promising methods for addressing the growing challenge of water sustainability (Reznik et al., 2019). Using a constructed wetland is among the Nature-Based Solutions (NBS), the next frontier in environmental management, leveraging natural processes to address water quality as it is reintroduced for community use. Along with constructed wetlands, these practices may make it possible to harvest rainwater or water from industrial processes. As a result, communities around the globe are looking towards NBS as both a primary and a secondary means of water remediation.

Despite growing support for NBS, these practices have only recently begun to capture the interest of the public and of what researchers refer to as "stakeholders," with co-benefits as the primary motivators of support (Giordano et al., 2020). The term "stakeholders" can be broadly defined as individuals or bodies that impact or are impacted by the design, implementation, or performance of NBS (De Trift et al., 2026). Without clearer lines drawn between these NBS approaches and improved public health and increased financial opportunities, it may take longer to inspire the same confidence and support in communities where traditional, grey infrastructure dominates the landscape of environmental engineering practices. A key issue with implementation is a lack of knowledge and education regarding the role of NBS and alternative water sources in such communities where grey infrastructure dominates. So-called stakeholders are concerned with the viability of NBS options in terms of cost-effectiveness and reliability compared with traditionally engineered options (Seddon et al., 2020).

The Local Context

Many governing and conservation bodies have implemented grants, fines, incentives, and signage to educate the public, but when funds are misused, these efforts may falter (Gibson et al., 2023). Locally, the San Antonio River Authority (SARA) has a dedicated education team that provides curricula, river camps, pre-made presentations, and hands-on experiences to motivate people of all ages to engage meaningfully with community waterways. In a similar vein, the San Antonio Water System (SAWS) has specialized education programs aimed at establishing a water-literate community through youth engagement. Both educational and community-forward engagement have been shown to increase public acceptance, outperforming passive education in many other areas of research (genome editing, renewable energy projects, biotechnology), so why not in the context of water resources (Abdulkareem et al 2024; Etchegary et al., 2015; Jimenez et al., 2022; Pathiranage et al., 2024)?

Our goal was to help students from a local secondary school and undergraduates undertaking a biology degree to engage with NBS through case studies and to understand the vital role of informed decision-making in determining whether a community would accept or reject water reuse. We partnered with the Castroville Wastewater Treatment Plant and developed a pair of case studies, along with a knowledge and attitude survey, to test whether a narrative-style, local, data-driven case study could help them move towards engagement with and acceptance of water reuse and the benefits of NBS.

Box 1. Research Questions Guiding the Project

- What is the existing acceptance of NBS across varied contexts? Which models of community engagement are most strongly associated with public acceptance of NBS in these varied contexts?
- Can exposure to a case study that embeds local data increase acceptance and understanding of NBS?
- How does effluent release impact parameters in a local water body with a wetland? Does proximity to the wetland reduce the impact? Is the impact sustained as the distance increases from the wetland?
- To what extent does involvement in a case-study "research experience" improve students' engagement with and appreciation of nature-based solutions?

Materials and Methods

The project combined an original field-based data collection effort with a course-based curriculum. This meant that the data being analyzed in the classroom were the same data being generated to answer our research questions about the wetland's capacity to remediate the wastewater plant effluent. Samples were collected monthly from three sites along a constructed wetland that receives effluent from the Castroville plant, as well as upstream and downstream sites on the Medina River, from February to July, 2026 (Figure 1). Samples were analyzed for nitrate and for phosphates using a portable spectrophotometer, and DNA extracted from the samples was sequenced to characterize the wetland's microbial community (by Plasmidsaurus). These data showed a modest but consistent decline in nitrates as the effluent moved along the wetland, and a detectable presence of DNA from taxa associated with antibiotic resistance in the effluent, which became the backbone of the data in the case studies rather than a hypothetical scenario typical of existing case studies. The research was thus used to construct two linked case studies for use in both K-12 and undergraduate settings. The first case study is a narrative-based one: the students follow a fictionalized resident of a small Texas town as she attends a city council meeting and hears from a variety of

FIGURE 1. Sites for Collection of Water Samples

stakeholders, including the plant operator and a panel of concerned citizens, each with a different stake in whether or not the town's treated wastewater effluent should be used to irrigate the city's park. The second case study was more data-driven, with the students playing the role of consultants employed by the same town council. They must interpret real data on nitrate and phosphate concentrations, as well as *Escherichia coli (E. coli)* counts. They would compare the upstream and downstream locations and consider policy options before making a recommendation in the form of a memo. At either end were pre- and post-tests that measured knowledge, engagement, and attitudes. This two-set case study design would enable us to determine whether combining a story with a data-driven experience would have a greater impact than either alone.

This project formed the basis of the first author's master's thesis research. The materials were piloted with undergraduate students at Texas A&M University-San Antonio, under IRB oversight, and modified versions were administered to K-12 students, with effectiveness being self-reported by their classroom teacher. A further

subset of seven students tested the material over the summer as part of an NSF Research Experiences for Undergraduates (REU) program, where participants conducted research at a constructed wetland in a local water body, adding real field-based experience to the case study they completed.

Box 2. Case Study and Field-Based Activities by Participating Students

- Reading and discussing a narrative case study depicting a community considering the fate of its treated wastewater
- Interpreting real data on phosphate and nitrate concentrations along with numbers of E. coli from a partner wastewater treatment plant
- Comparing upstream and downstream water quality data compared with that of the constructed wetland
- Drafting a written memo making a recommendation to the fictional city council that would make mention of the data
- Monthly field collection of water samples at three wetland sites as well as the upstream and downstream controls
- Water analysis in the lab for nitrate and phosphate concentrations using a portable spectrophotometer
- Nucleic acid extraction and sequencing (done by a company) to characterize the wetland microbial community
- Completion of a paired pre- and post-test instrument that measures knowledge, attitudes, and engagement

Both case studies and associated materials are available for download as resources in the QUBES hub available here: https://qubeshub.org/publications/6186/1

Results and Discussion

How Students Were Evaluated

To ensure that the students participated honestly and to the best of their ability, our pre- and post-tests were ungraded, and we emphasized to the students that this was an assessment and study of their level of understanding as part of the research study. To us, honest answers were more valuable than expected ones. We actively discouraged them from "googling" the answers (this would be a concern for future at-home implementations). The instrument was designed to measure three dimensions:

- Knowledge – five multiple-choice items and two open-response questions scored against a four-level rubric
- Attitudes – twelve statements rated on a Likert scale
- Engagement – four open-ended reflection questions, with responses in the student's own words

We used a Wilcoxon signed-rank test to analyze the knowledge and attitude items. As the sample size was small, we conducted a sensitivity analysis by excluding two respondents who were flagged for unusually strong reversals between pre- and post-test attitude scores. Students' identities were not collected. Responses were coded prior to analysis. Participation was voluntary, and consent was obtained under the PIs' IRB protocol. For K-12 students, where a full quantitative instrument was not appropriate, effectiveness was assessed qualitatively through the teacher's self-reflection.

Student Success, Limitations and Reflections

Knowledge scores on the open-ended questions improved from the pre-test to the post-test for nearly all respondents (Figure 2). We also noted that item-level accuracy on the multiple-choice questions rose where there was room to grow. The most encouraging finding concerned public acceptance. At the outset of our project, during case study 1, most students were undecided about whether the town should use treated effluent to irrigate the city's park.

We observed more mixed results in our examination of attitudes (Figure 3). Most of the students already held favorable views towards resource conservation before the pre-test (not unexpected, given the course and their majors). There was a high ceiling of acceptance that limited how much movement was possible. However, two respondents showed a sharp negative swing in attitude

FIGURE 2. Individual Change in Open-Response Scores

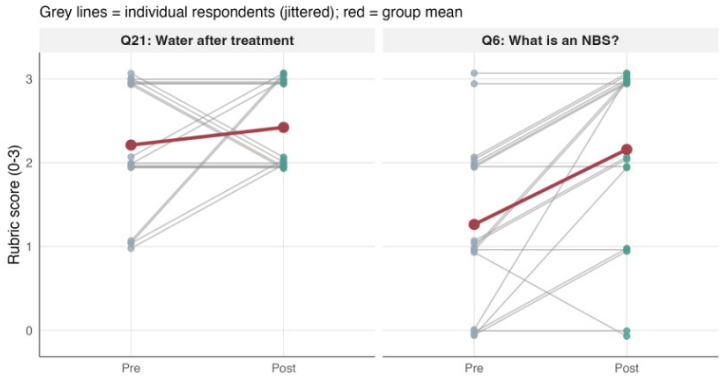
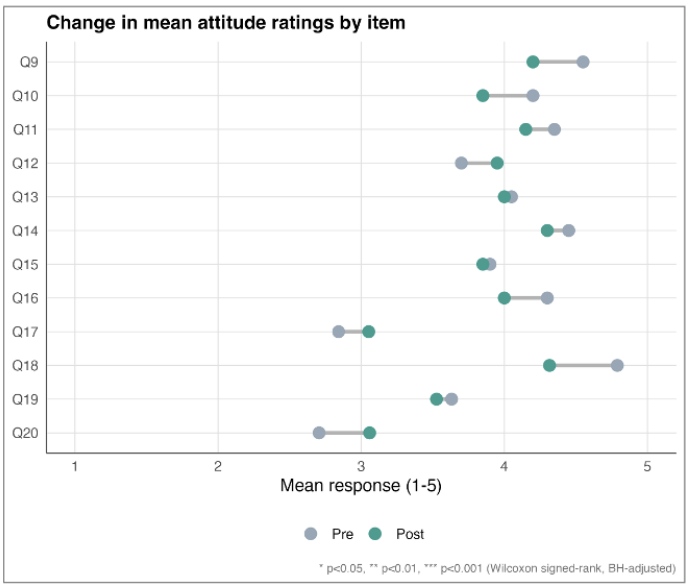


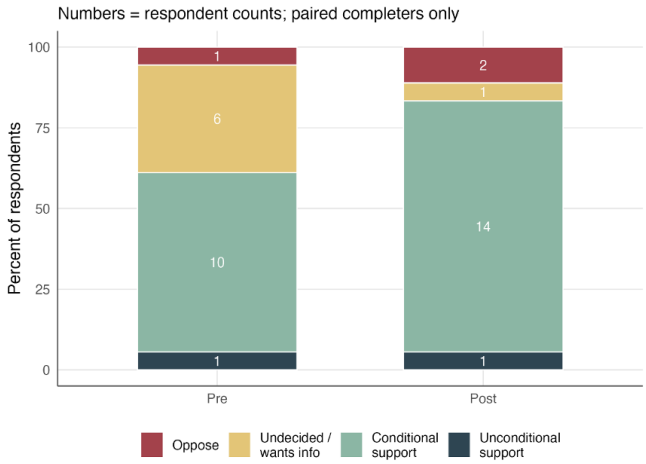
FIGURE 3. Barbell Chart of Change in Mean Attitudes by Item



scores. We suspect this may reflect a misreading of the scale or even a form of disengagement from the post-test, rather than a true reversal of attitude. Given this, the authors recognize the need to re-do and expand our pilot sampling beyond upper-level biology majors. Having completed both case studies, the gap among undecided students almost closed, with four individuals moving into conditional support and only one moving towards opposition (Figure 4).

One major limitation we identified early in the pilot was time. This practical barrier was owing to the limited time available in a single lab session. Conducting both the case studies and the pre- and post-tests takes time away from classroom activities. When time was short, the

FIGURE 4. Support for Irrigating Public Spaces with Treated Wastewater (Q22)



post-test was administered instead of the second case study. In future iterations, we will move the data-driven case study to an at-home, out-of-class assignment to be completed before class time. We also recognize that we need to consider the audience, a range of majors, and to include freshmen to seniors.

The need for greater implementation is evidenced by the course- and grade-level-based variation in K-12 students' ceiling of knowledge. 10th-grade students in an environmental systems class reported no knowledge of NBS at the outset of the pre-test, though they were often successful in selecting the definition when given multiple-choice options. 12th-grade students in a dual-credit biology course were able to correctly identify NBS in multiple-choice questions and offered robust short-answer responses. As previously discussed, time constraints prevented the implementation of the second case study. One of the greatest successes of our project was the connections that we made with the director of the Castroville Wastewater Plant. He was willing to share real, plant-specific data and discuss the issues. This real-world, locally sourced data likely had a much greater impact than a hypothetical scenario from elsewhere, and we now have an ongoing community-engaged project with real impact to build upon.

Box 3. Key Findings from the Pilot

- Nitrate concentrations declined significantly as the effluent moved through the constructed wetland (p values ranging from 0 to 0.042 across sites).
- Phosphate concentrations were more varied by date but remained consistently higher at the wetland sites than at the upstream and downstream control sites.
- Burholderiaceae, a taxon associated with antibiotic resistance, was the most abundant group we identified through sequencing water collected from the wetland.
- Knowledge responses measured with the rubric showed improvement from pre-test to post-test for all but one respondent.
- The number of students undecided about reusing water effluent for park irrigation decreased after using both case studies, with most moving towards unconditional support.

Summary and Future Directions

NBS like constructed wetlands are a proven tool for water remediation, mitigating the presence of nutrients, antibiotic resistance genes, and other water contamination concerns. We recognize that the efficacy of wetlands must be observed over a prolonged period to determine how well they withstand other factors, such as climate change and changes in pollutant types and concentrations. We must also consider equity in their construction and distribution. Educated and affluent communities are seeing the most direct benefits now, and the potential for these solutions to become class-specific looms. This is counterintuitive given the cost-efficiency of these designs, and resistance to NBS could be overcome through community engagement. We also recognize that we need to fund and support research on NBS, especially as we enter a more pivotal point than ever before regarding water accessibility. Government and government-adjacent bodies could seek a path forward that helps build trust among themselves, other stakeholders, the community at large, and the scientific community by funding and encouraging education on these practices. As the push for a more ecologically mindful world grows, education remains the most conducive platform for community change.

In our efforts to promote data-driven decision-making, we paired our case studies with locally acquired data. Our pilot application with Texas A&M University-San Antonio biology students provides a multifaceted proof of concept and a model for a way forward. While the results of the initial wetland monitoring are nuanced, they paint a picture of an effective wetland remediation model with the potential for greater impact through expansion to match the suggestion that increased retention time correlates with greater remediation. Long-term monitoring built into the local school curriculum poses a real opportunity to learn about how attitudes toward NBS can be changed.

The deployment of the case studies offers an even more nuanced glimpse into the mindsets of young people with the greatest potential for community change. While the observed group of respondents scored high in both attitudes and knowledge, both groups saw gains, even with high ceilings. While a small percentage were swayed away from the validity of NBS, a large portion of uninformed and undecided respondents moved toward greater understanding and, with that, increased support of NBS. This model of engagement has the potential to expand acceptance of NBS across multiple levels of the community, thereby increasing the availability and acceptance of recycled water applications.

In future semesters, we intend to refine the timing of the two case studies, expand our K–12 pilot with a fuller instrument, and pursue long-term monitoring of the wetland. We need to better understand the durability of NBS and to consider equity of access to NBS. We are also especially interested in engaging with rural Texas communities, who are too often left out of both data collection and the conversations about water reuse. It is in these rural communities that NBS methods, adopted evenly and equitably along with stakeholder buy-in, could have the greatest impact on water scarcity.

About the Authors

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References

Abdulkareem, A. K. (2024). Examining the role of community engagement and capacity building in the acceptance of renewable energy projects: The mediating role of trust. *Public Administration and Regional Studies*, 17(1), 22–48.

Ayaz, S. Ç. (2008). Post-treatment and reuse of tertiary treated wastewater by constructed wetlands. Desalination, *10th IWA International Specialized Conference on Diffuse Pollution and Sustainable Basin Management*, 226(1), 249–255. https://doi.org/10.1016/j.desal.2007.02.110

De Trift, L., Schlemm, A., Ronoh, E. K., Yimer, E. A., & Van Griensven, A. (2026). Modelling nature-based solutions for improving surface water quality: A comprehensive review and synthesis. *Nature-Based Solutions, 9*, 100344. https://doi.org/10.1016/j.nbsj.2026.100344

Etchegary, H., Green, J., Parfrey, P., Street, C., & Pullman, D. (2015). Community engagement with genetics: Public perceptions and expectations about genetics research. *Health Expectations, 18*, 1413–1425. https://doi.org/10.1111/hex.12122

Gibson, K. E., Lamm, A. J., Lamm, K. W., & Holt, J. (2023). Integrating the theory of planned behavior and motivation to explore residential water-saving behaviors. *Water, 15*(17), 3034. https://doi.org/10.3390/w15173034

Giordano, R., Pluchinotta, I., Pagano, A., Scrieciu, A., & Nanu, F. (2020). Enhancing nature-based solutions acceptance through stakeholders' engagement in co-benefits identification and trade-offs analysis. *Science of the Total Environment, 713*, 136552. https://doi.org/10.1016/j.scitotenv.2020.136552

Jimenez, J., Gamble-George, J., Danies, G., Hamm, R. L., & Porras, A. M. (2022). Public engagement with biotechnology inside and outside the classroom: Community-Focused approaches. GEN Biotechnology, 1(4), 346–354. doi:10.1089/genbio.2022.0024

Leijnse, M., Bierkens, M. F. P., Gommans, K. H. M., Lin, D., Tait, A., & Wanders, N. (2024). Key drivers and pressures of global water scarcity hotspots. *Environmental Research Letters, 19*(5), 054035. https://doi.org/10.1088/1748-9326/ad3c54

Pathiranage, W. B., Bray, L., Jones, K., Redwine, N., Saralvarez, J., & D'Alessio, M. (2024). Perception and acceptance towards water reuse in the Southeast United States: A public survey. *Science of the Total Environment, 908*, 168224. https://doi.org/10.1016/j.scitotenv.2023.168224

Reznik, A., Dinar, A., & Hernández-Sancho, F. (2019). Treated wastewater reuse: An efficient and sustainable solution for water resource scarcity. *Environmental and Resource Economics, 74*(4), 1647–1685. https://doi.org/10.1007/s10640-019-00383-2

Schumacher, A. M., Carver, J. L., Astudillo, C., & Schumacher, Y. (2025, March 13). What to know about Texas' looming water crisis. *The Texas Tribune*. https://www.texastribune.org/2025/03/13/texas-water-explained-supply-demand/

Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794), 20190120. https://doi.org/10.1098/rstb.2019.0120

Texas Water Development Board. (n.d.). *Water reuse*. https://www.twdb.texas.gov/innovativewater/reuse/

SPECIAL SECTION

TEACHING THROUGH WATER

Educating the Educator: Using Agriculture to Build Science Literacy

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Introduction

How do we prepare students to make informed decisions about food, water, energy, biotechnology, and environmental sustainability, when many of their science teachers have had little or no formal training in agriculture? Nourish the Future addresses this challenge by starting with the educator.

Nourish the Future, or NTF, is a free national education initiative developed by science teachers for science teachers. Its goal is to increase agricultural literacy by helping educators connect the science they already teach to modern agriculture, food production, environmental sustainability, biotechnology, and agricultural careers (Nourish the Future, 2026a). The program is supported by agricultural commodity organizations and agribusinesses, including the national Soy Checkoff program, Bayer Crop Science, and state commodity groups.

This funding provides professional learning, curriculum, classroom materials, and supplies to participating teachers at no cost.

The strategy is simple but powerful. Agriculture provides an authentic context for required science content. NTF equips educators through industry experiences, teacher-tested curriculum, and practical classroom materials. Teachers bring those experiences to students and other educators, multiplying the impact throughout their careers.

Teachers Teaching Teachers

The foundation of NTF is that it is for teachers, by teachers. Teacher Leaders do not simply present curriculum. They engage educators as learners. Teachers collect data, manipulate materials, analyze evidence, make mistakes, ask questions, and discuss results. By experiencing the investigation first as learners, teachers encounter the same questions, procedural challenges, data interpretation problems, and opportunities for scientific reasoning that their students will encounter. A biology teacher who has never tested soil nutrients performs the test. An environmental science teacher investigates how agricultural practices affect a watershed. A chemistry teacher can explore biofuels through concepts already present in the curriculum.

Agriculture is the context for teaching science, not an additional subject competing for instructional time.

NTF uses two complementary professional learning models. The **National Teacher Leader Cohort** develops educators who deepen their understanding of modern agriculture, inquiry-based instruction, leadership, and agricultural careers. These teachers become part of a national network that shares curriculum and supports other educators.

The second model brings professional learning directly to states through two-day **Nourish the Future Feeding and Fueling the World** (NTF FFTW) workshops. During 2026, NTF FFTW workshops were held in North Carolina, Alabama, North Dakota, Missouri, Indiana, Kentucky, Wisconsin, Nebraska, Michigan, and Minnesota.

IMAGE 1. NTF FFTW WI 2026 Teachers and Industry Leaders Including Secretary of The Wisconsin Department of Agriculture, Trade and Consumer Protection, Randy Romanski

Removing Barriers to Implementation

NTF FFTW workshops immerse middle and high school educators in phenomena-based investigations that are aligned with Next Generation Science Standards and connect biology, chemistry, environmental science, biotechnology, and other STEM disciplines to food and fuel production.

Each participating teacher receives equipment and classroom supplies valued at up to $300. Materials can include water quality and watershed equipment and LaMotte soil testing kits. Teachers therefore leave the workshop not simply knowing about an activity but prepared to implement it.

The impact can also extend beyond individual classroom lessons. Some participants teach high school research courses yet before NTF training had never considered directing students toward agricultural research. Exposure to agricultural biotechnology, soil science, water quality, plant science, biofuels, and food systems gives teachers new areas for student research, and introduces students to agricultural STEM disciplines and career pathways they may not previously have encountered.

Water as an Entry Point to Civic Science

The NTF water quality curriculum demonstrates how this strategy connects science learning with civic engagement. Water connects communities, and decisions involving agriculture, development, stormwater, recreation, and ecosystem protection have consequences beyond property lines.

The NTF middle school water quality curriculum creates a particularly effective progression. Students move from watershed processes to human impacts to nutrients to abiotic testing to biological indicators and finally to evidence-based remediation (Nourish the Future, 2026b).

IMAGE 2. NTF FFTW KY teachers investigate water quality with the Understanding Watershed Activity

Students investigate watersheds, soil profiles, erosion, nutrient impacts, and relationships between land use and water quality. They can measure temperature, turbidity, pH, dissolved oxygen, nitrogen or nitrate, and phosphorus or phosphate. They investigate soil infiltration and erosion and examine macroinvertebrates as indicators of ecosystem health. Finally, students combine physical, chemical, and biological evidence to evaluate water health and develop remediation plans.

This final step is essential to civic engagement.

Students are not simply asked whether water is polluted. They must consider evidence, determine what may be influencing the system, and propose actions that could improve it.

The progression mirrors the reasoning citizens need when confronting environmental issues in their communities. They observe a problem, gather evidence, evaluate explanations, understand human impacts, and consider solutions.

IMAGE 3. Nourish the Future Resources for Students Investigating Land Use Impacts (including macroinvertebrates and water test cards)

From Classroom Science to Community Science

Students can examine a local water system, identify surrounding land uses, and predict possible influences. Physical, chemical, and biological evidence can then be compared with maps, rainfall patterns, land use information, or publicly available environmental data.

The teacher's role changes from providing the correct explanation to helping students determine what claims the evidence supports.

This is where agricultural literacy and civic scientific literacy intersect. Agriculture should neither automatically be blamed for an environmental problem nor automatically be excluded as a possible contributor. Students should investigate evidence; they should examine agricultural practices intended to reduce nutrient and sediment loss, including vegetative buffers, nutrient management, reduced tillage, and practices that increase soil infiltration.

Students begin moving beyond statements such as "pollution associated with agriculture" or "farmers protect the environment" toward better questions. What does the evidence show? What practices are being used? What are the tradeoffs? What additional evidence is needed before making a recommendation?

That is science education serving civic engagement.

Extending Learning Through Research and Biotechnology

At the high school level, NTF water curriculum extends learning into biodiversity and biotechnology. Students can examine freshwater plankton biodiversity and use Simpson's Index of Diversity to investigate aquatic ecosystems. Water bioinformatics allows students to use

IMAGE 4. NTF FFTW NC 2026: Education And Outreach Coordinator, Sarah Dinger leads a tour of the NC State Vegetable Pathology Lab

DNA sequences and the National Center for Biotechnology Information database to identify organisms represented in water samples (Nourish the Future, 2026c). These experiences demonstrate that modern environmental monitoring combines field observations, chemistry, biology, mathematics, genetics, and computational tools.

NTF Teacher Leaders also include college educators. Dr. Brian Shmaefsky of Lone Star College, a former president of the Society for College Science Teachers, brings experience in environmental science, biology, faculty mentoring, and professional learning (Nourish the Future, n.d.). College faculty participation helps connect secondary science, undergraduate STEM learning, and agricultural career pathways. Agricultural science teachers provide specialized expertise and pathways, while general science teachers provide another avenue for expanding agricultural literacy through biology, chemistry, environmental science, earth science, and other STEM courses.

The Teacher Multiplier Effect

A student experiences a lesson once. An educator can teach that lesson repeatedly.

A science teacher reaching 130 students each year can reach 1,300 students over ten years. When that teacher shares an NTF investigation through district professional development, a state science teachers conference, or a professional network, the original professional learning investment begins reaching students who were never taught by the original participant. This is especially important because most students will never enroll in an agriculture course. They do, however, take biology, environmental science, chemistry, earth science, and other science courses.

Educating the educator reaches not only today's students but future students throughout that educator's career.

Teacher leadership therefore scales agricultural and civic science literacy. Practicing educators understand classroom constraints and can tell colleagues, "I used this with my students, and this is how I made it work."

Preparing Students for Earth and Beyond

Agricultural literacy extends beyond traditional farming. Food, water, soil, energy, biotechnology, and sustainability are civic issues on Earth and will become survival issues as humans move beyond it. In future settlements on the Moon, Mars, or elsewhere, humans will again become pioneers, with everyone connected to food production and resource management. Students investigating these systems today are developing scientific knowledge needed to solve problems on Earth and eventually sustain communities beyond it.

Conclusion

The practical teaching strategy demonstrated by Nourish the Future is not simply providing teachers with more curriculum. It is building teacher capacity. Agriculture provides an authentic context for science, while NTF prepares teachers to use that context through firsthand investigations, classroom ready curriculum, equipment, and connections with scientists, agricultural professionals, college faculty, and other educators.

The National Teacher Leader Cohort and NTF FFTW workshops extend that impact as teachers reach new students each year and share their experiences with other educators. Water quality demonstrates the result. Students collect and interpret evidence, investigate

human interactions with natural systems, consider possible solutions, and use science to participate thoughtfully in civic decisions.

That is agricultural literacy. That is scientific literacy. And that is civic engagement.

About the Authors

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Resources

- **Nourish the Future:** https://nourishthefuture.org/
- **Nourish the Future Water Quality Curriculum:** https://nourishthefuture.org/curriculum/water-quality

References

EducationProjects.org. (2026). *For teachers*. https://educationprojects.org/teachers

Nourish the Future. (n.d.). *Brian Shmaefsky*. https://nourishthefuture.org/teachers/brian-shmaefsky

Nourish the Future. (2026a). *Nourish the Future: A national education initiative developed by science teachers for science teachers.* https://nourishthefuture.org/

Nourish the Future. (2026b). *Water quality: Middle school.* https://nourishthefuture.org/curriculum/water-quality/ms

Nourish the Future. (2026c). *Water quality: High school.* https://nourishthefuture.org/curriculum/water-quality/hs

Stiens, S. (2022, October 31). *New Jersey State Teacher of the Year shares recipe for personal success*. National Corn Growers Association. https://ncga.com/stay-informed/media/in-the-news/article/2022/10/new-jersey-state-teacher-of-the-year-shares-recipe-for-personal-success

SPECIAL SECTION

TEACHING THROUGH WATER

Dark Waters: A Case Study

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Abstract

The NSF-funded Retention, Relevance, and Readiness Through Bridging Water Security Issues in San Antonio (WaTR3) project aimed to address two persisting challenges. The first being limited integration of limited integration of local water issues into existing courses in the Water Resources Science and Technology (WaTR) program and in STEM program courses. The second one is limited career pathways limited career pathways for students interested in water-related professions. This project developed water-focused curricular materials for an Organic Chemistry I course centered on a case study of per- and polyfluoroalkyl substances (PFAS) contamination. The case study was used by students to connect core chemistry concepts, including chemical persistence and toxicology, to real-world consequences, fulfilling the broader aim of teaching through the issues. Students also had the opportunity to participate in a two-week Research Experiences for Undergraduates (REU) program held at Texas A&M University-San Antonio, and faculty presented their project at the SENCER Summer Institute as part of the project's professional development requirement.

Introduction

This project was a subaward to Palo Alto Community College from the Texas A&M University-San Antonio WaTR3 program funded by the National Science Foundation, which was established to emphasize the importance of integrating local water issues into the existing WaTR program and STEM program courses. For the chemistry program, this project was the first attempt to incorporate a localized community water issue into the curriculum.

In spring and summer of 2025, rigorous brainstorming sessions were conducted in learning communities to design curriculum models for different disciplines. A case study model based on a real-world water issue mediated by per- and polyfluoroalkyl substances (PFAS) contamination was selected for Organic Chemistry I during Fall 2025. PFAS are synthetic chemicals that do not break down easily because they contain strong carbon-fluorine bonds, which is why they are commonly called "forever chemicals" (Cordner et al., 2019; Evich et al., 2022). PFAS have become a national environmental health concern because of their contamination of drinking water, and they have been identified as a major threat to Texas water systems. In addition, the study of PFAS enables the incorporation of critical Organic Chemistry I concepts, including functional groups, polarity, and spectroscopic analysis. To link PFAS concepts to the levels of contamination reported across Texas (Dasu et al., 2022; Kurwadkar et al., 2022; Valdiviezo et al., 2022), students created a poster using instructor-provided guidelines and rubrics, and they completed a survey that gathered feedback on their experiences in the case study project.

The case study had two objectives: first to explore how the functional groups of organic molecules influence their solubility in water, and second to examine the chemical principles behind detecting major PFAS, using chromatography and spectroscopy, along with the importance of safe handling and disposal of environmental contaminants such as PFAS (Chow et al., 2021; Evich et al., 2022). These objectives were developed based upon the student learning outcomes identified for lecture and laboratory components of the Organic Chemistry I course syllabus.

The following student learning outcomes were met by the project. PFAS was used as an example while discussing each of these student learning outcomes.

1. Explain the chemical and physical behavior of organic compounds based on their functional groups, and predict this behavior for a compound whose functional group is known.
2. Determine the factors affecting the solubility of organic compounds in different polar and nonpolar solvents.
3. Apply chromatographic and spectroscopic techniques to elucidate the structure of organic molecules.
4. Utilize chemical knowledge to understand safe handling of chemicals and appreciate the role of chemistry in addressing societal challenges in areas such as energy, medicine, and health.
5. Apply chemical knowledge to ensure safe handling of chemicals and appreciate the role of chemistry in addressing societal challenges in multiple areas, especially energy, medicine, and health.

Case Study Assignment: Understanding PFAS through Dark Waters

Dupont, a pioneer in the development of Teflon-coating technology used PFOA (Perfluorooctanoic acid), a synthetic chemical, in their production plant. PFOA is a member of the PFAS group of chemicals, which build up in the human body because the body cannot break them down and remove them. Without proper disposal of this byproduct, DuPont company contaminated several water districts near its production unit, causing chronic illness among its employees and birth defects among children in the surrounding community. DuPont concealed these dangers for decades until an attorney began investigating the issue and brought the truth to light.

The film *Dark Waters* tells the true story of this investigation.

Interactive, Panopto videos of 20-minute modules were created from the *Dark Waters* film, with two interactive quizzes embedded in every module. It was a semester-long activity. The quizzes were graded for participation. Students were divided into groups on Canvas, the Learning Management System at Palo Alto College, to collaborate and discuss the questions which were tied to the learning objectives. The students used the discussion board to share insights and develop a comprehensive understanding of the topics. The discussion questions addressed PFAS utilization, solubility, analytical approaches, and structural elucidation. Students were encouraged to identify sources of PFAS exposure and suggest ways to

minimize it. Students also completed a survey on their experiences and understanding of the case study project.

The case study was presented in the SENCER (Science Education for New Civic Engagements and Responsibilities) Summer Institute, the goal of which is to connect basic science and civic engagement by teaching through issues.

Research Poster Presentation

To connect the case study to a local water issue, students were given the following prompt along with guidelines and a rubric to conduct research on the prompt and prepare a poster for presentation: "The EPA set its first-ever limits, in ppt (parts per trillion), for five types of PFAS chemicals in drinking water, and nearly 50 Texas public water systems have reported exceeding the new limits for at least one of them" (Martinez, 2024, 2025). Using this prompt, students conducted research on this topic and created a poster addressing the following major points.

- Major classes of PFAS
- Sources of PFAS in Texas (include 4-5 sources)
- Detection methods
- Health and environmental impact
- Limits and safety measures

The poster also served as a resource for the faculty during the project presentation at the SENCER Summer Institute.

The concern about limited career opportunities for students and water professionals was addressed by creating an undergraduate research program (REU), in which students participated in two weeks of paid research training in Texas A&M University-San Antonio laboratories to prepare them for the workforce.

Results and Conclusion

This project gave students insights into functional groups, chemical analysis, health effects (Fenton et al., 2021; Panieri et al., 2022), regulatory policies (O'Sullivan Bakshi et al., 2025), and environmental impacts of PFAS, as reflected by their survey responses. Figure 1 compares the structure of acetic acid (vinegar) to PFAS, which have similar functional groups in them. As one student commented, this project helped them better understand how the structure of the PFAS molecules makes them water-repellent, heat-resistant, and non-destructible (Figure 1). The survey responses on interesting aspects of PFAS, detection methods of PFAS, and familiarity of students with PFAS were plotted as a percentage in Figure 2, reflects a good percentage of students have gained understanding about PFAS. The students were able to connect chemical persistence and toxicology to real world consequences (Dasu et al., 2022; Kurwadkar et al., 2022). The project increased the students' awareness of the proper handling and disposal of hazardous waste, and how to reduce damage to the environment and impacts on human life. New regulatory actions continue to be introduced nationwide to limit the exposure to PFAS, and research activities continue to help us better protect public health (Environmental Protection Agency, 2026). Students in this course became aware of hazardous chemical disposal, safety procedures, and regulatory measures (Figure 2) and had the opportunity for two weeks of paid research training. Faculty had the opportunity to present at the SENCER Summer Institute. This project established a foundation for educators in a variety of disciplines to incorporate contemporary real-world issues into their curriculum and instruction. It promoted students' critical thinking and inquiry and encouraged them to apply their academic knowledge to the issues in their local surroundings.

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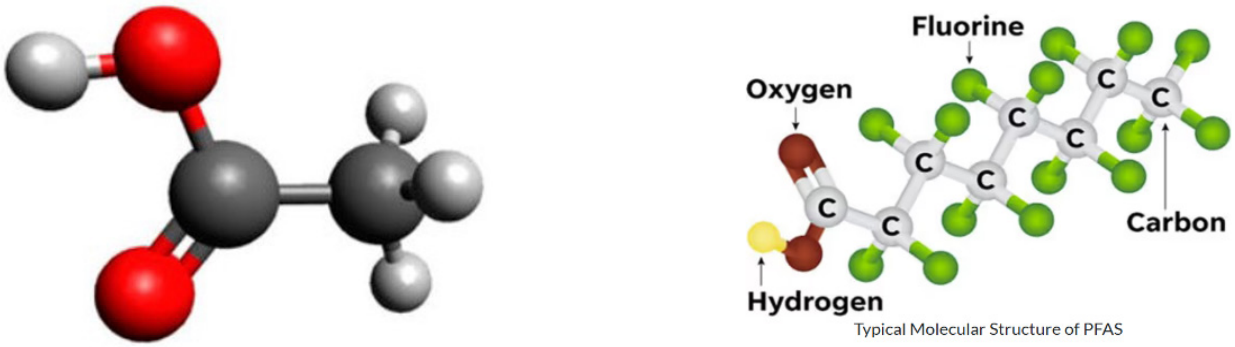
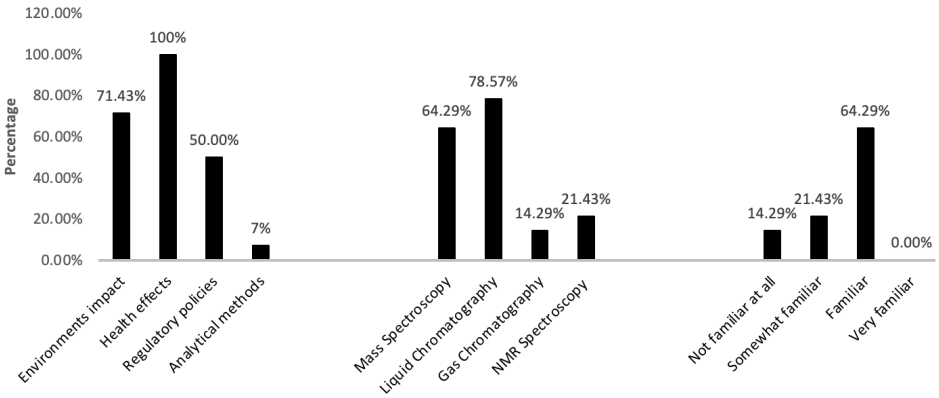
FIGURE 1. Structure Comparison of Acetic Acid and PFAS



ACETIC ACID (VINEGAR) **PFOA**

FIGURE 2. Results of Student Survey on PFAS Case Study



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References

Chow, S. J., Ojeda, N., Jacangelo, J. G., & Schwab, K. J. (2021). Detection of ultrashort-chain and other per- and polyfluoroalkyl substances (PFAS) in U.S. bottled water. *Water Research, 201*, 117292. https://doi.org/10.1016/j.watres.2021.117292

Cordner, A., De La Rosa, V. Y., Schaider, L. A., Rudel, R. A., Richter, L., & Brown, P. (2019). Guideline levels for PFOA and PFOS in drinking water: The role of scientific uncertainty, risk assessment decisions, and social factors. *Journal of Exposure Science & Environmental Epidemiology, 29*(2), 157–171. https://doi.org/10.1038/s41370-018-0099-9

Dasu, K., Xia, X., Siriwardena, D., Klupinski, T. P., & Seay, B. (2022). Concentration profiles of per- and polyfluoroalkyl substances in major sources to the environment. *Journal of Environmental Management, 301*, 113879. https://doi.org/10.1016/j.jenvman.2021.113879

Environmental Protection Agency. (2026). *Per- and Polyfluoroalkyl Substances (PFAS): Final PFAS National Primary Drinking Water Regulation*. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

Evich, M. G., Davis, M. J., McCord, J. P., Acrey, B., Awkerman, J. A., Knappe, D. R., Lindstrom, A. B., Speth, T. F., Tebes-Stevens, C., Strynar, M. J., Wang, Z., Weber, E. J., Henderson, W. M., & Washington, J. W. (2022). Per- and polyfluoroalkyl substances in the environment. *Science, 375*(6580). https://doi.org/10.1126/science.abg9065

Fenton, S. E., Ducatman, A., Boobis, A., DeWitt, J. C., Lau, C., Ng, C., Smith, J. S., & Roberts, S. M. (2021). Per- and polyfluoroalkyl substance toxicity and human health review: Current state of knowledge and strategies for informing future research. *Environmental Toxicology and Chemistry, 40*(3), 606–630. https://doi.org/10.1002/etc.4890

Kurwadkar, S., Dane, J., Kanel, S. R., Nadagouda, M. N., Cawdrey, R. W., Ambade, B., Struckhoff, G. C., & Wilkin, R. (2022). Per- and polyfluoroalkyl substances in water and wastewater: A critical review of their global occurrence and distribution. *Science of The Total Environment, 809*, 151003. https://doi.org/10.1016/j.scitotenv.2021.151003

Martinez, A. (2024, April 16). Dozens of Texas water systems exceed new Federal limits on "forever chemicals." *The Texas Tribune*. https://www.texastribune.org/2024/04/16/texas-pfas-forever-chemicals-public-water-systems-epa-limit/

Martinez, A. (2025, June 2). Bills aimed at studying, restricting "forever chemicals" in Texas fail. *The Texas Tribune*. https://www.texastribune.org/2025/06/02/texas-pfas-forever-chemicals-bills-legislation-fail/

O'Sullivan Bakshi, S., Dakin, Z., Monaghan, M., & van Gerwen, M. (2025). Per- and polyfluoroalkyl substances (PFAS) in the United States: Current knowledge and regulatory context. *Science of The Total Environment, 1003*, 180711. https://doi.org/10.1016/j.scitotenv.2025.180711

Panieri, E., Baralic, K., Djukic-Cosic, D., Buha Djordjevic, A., & Saso, L. (2022). PFAS molecules: A major concern for human health and the environment. *Toxics, 10*(2), 44. https://doi.org/10.3390/toxics10020044

Valdiviezo, A., Aly, N. A., Luo, Y.-S., Cordova, A., Casillas, G., Foster, M., Baker, E. S., & Rusyn, I. (2022). Analysis of per- and polyfluoroalkyl substances in Houston Ship Channel and Galveston Bay following a large-scale industrial fire using ion-mobility-spectrometry-mass spectrometry. *Journal of Environmental Sciences, 115*, 350–362. https://doi.org/10.1016/j.jes.2021.08.004