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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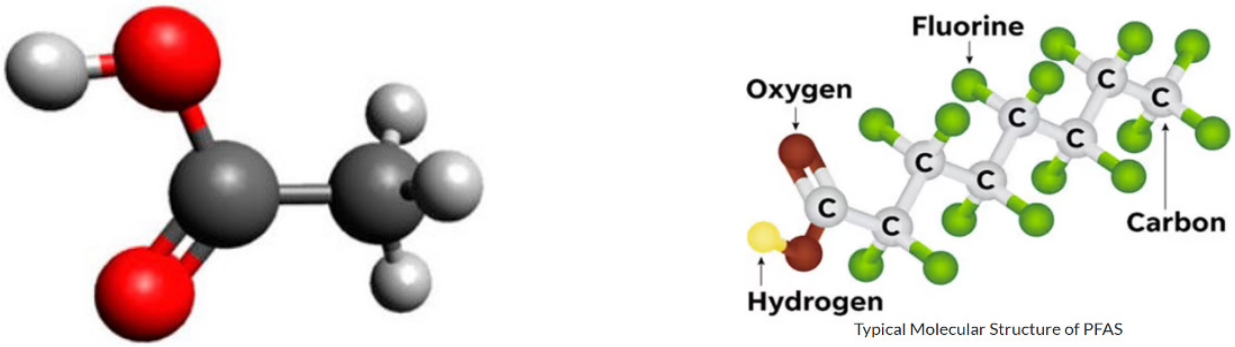
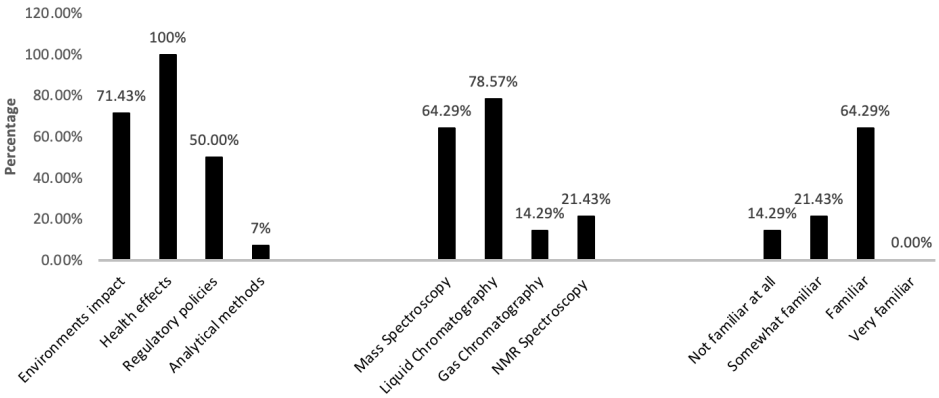
FIGURE 1. Structure Comparison of Acetic Acid and PFAS



ACETIC ACID (VINEGAR) **PFOA**

FIGURE 2. Results of Student Survey on PFAS Case Study



About the Author

Jeena Joseph is an assistant professor of chemistry at Palo Alto College, San Antonio, TX. She teaches general chemistry and organic chemistry. Dr. Joseph has established herself in both academia and research and has been instrumental in engaging students through innovative research projects and honors symposia. As a dedicated educator, she contributed significantly to curriculum development and student mentorship, fostering a dynamic learning environment that encourages scientific inquiry. She is also involved in civic engagement and community services.

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