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About the Journal

Science Education and Civic Engagement: An International Journal is an online, peer-reviewed journal. It publishes articles that examine how to use important civic issues as a context to engage students, stimulate their interest, and promote their success in mathematics and science. By exploring civic questions, we seek to empower students to become active participants in their learning, as well as engaged members of their communities. The journal publishes the following types of articles:

- ***Book & Media Reports***
- ***Point of View***
- ***Project Reports***
- ***Research***
- ***Review***
- ***Science Education & Public Policy***
- ***Teaching & Learning***

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From the Editors

Spring 2025 Issue

For the Spring 2025 issue of this journal, we are delighted to feature two project reports and a research article that highlight how civic engagement and experiential learning enhance student learning outcomes.

In recent years, scientists and the public have been paying more attention to microplastics—their ubiquitous presence in our environment, food, and drinking water, along with growing evidence of their detrimental impact on ecosystems and human health. In order to study the parameters and composition of microplastics, it is necessary to extract and isolate them from various samples. In this issue, a professor (**Gustavo Salazar**), a lecturer (**Alana P. Taylor**), and a former undergraduate student (**Liliana Driver**) from **Texas Woman's University** describe a novel chemical protocol to extract microplastics from soil samples, which greatly expands the scope of potential sample collection. This extraction procedure has been implemented by college students—both chemistry majors and non-majors—in a course that focuses on water in the environment from a global perspective. The authors also use their knowledge of microplastics as the foundation for outreach activities to younger students in K–12 education, with the goal of expanding the scope of the project to a full-scale citizen science initiative.

Service-learning has been recognized for several decades as a high-impact educational practice with ripe potential for fostering civic engagement. However, it can be challenging to implement a service-learning project within the structural and logistical constraints of a standard academic course. **Guang Jin** and **Pranshoo Solanki** at **Illinois State University** propose a creative solution to this challenge by creating extracurricular opportunities for students to participate in service-learning projects through the framework of a consulting company. The authors draw upon their collective expertise in environmental health, sustainability, and construction management to establish a variety of practical service-learning opportunities, such as using waste glass in construction materials. Students who participate in these projects report gains in professional development, team collaboration, solving complex problems, and effective communication. In addition, participating as consultants for real-world projects provide students with a greater sense of agency and impact throughout their service-learning experiences.

Continuing the theme of experiential learning, **Katherine Moccia** and **Bernadette Ludwig** at **Wagner College** have partnered with **Matthew Holben** at **Tennessee Tech University** to explore the impact of including an experiential learning component in a first-year college course that focuses on student mental health. The experiential activities included outreach to other students on campus to distribute mental health surveys, which were subjected to data analysis, visual display, and dissemination to the campus community. A cohort of 14 students participated in the experiential learning class, and their educational development was compared to 24 students in classes without an experiential component. Based on pre-post surveys for a variety of course learning objectives, students in the experiential learning class reported greater confidence gains for important skills in the realm of data literacy, such as creating graphs from data, comprehending the visual display of data, and communicating the interpretation of data to peers and professors. This research study demonstrates the value of using experiential learning as a real-world, civic context to enhance students' acquisition of important analytical skills in their first year of college.

We wish to thank all the authors for sharing their scholarly work with the readers of this journal.

Matt Fisher
Trace Jordan
Co-Editors-in-Chief

Marcy Dubroff
Managing Editor

An Interdisciplinary Methodology to Extract Microplastics from Soil: Laying the Groundwork for a Citizen Science Project

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Texas Woman's University

LILIANA A. DRIVER
Texas Woman's University

Abstract

The forming of microplastics in the environment continues be a global problem with damaging risks to ecosystems and human health. Currently, most microplastic studies concentrate on water and air, while research focus on terrestrial samples such as soil still lags behind. This project reports the first results of our effort to develop and implement a methodology to study microplastics in soil samples nested in a multidisciplinary teaching laboratory. Chemistry and non-chemistry students isolated and examined microplastics, typically finding blue microfibers, verified via optical microscopy. In addition, participants designed outreach activities to introduce microplastic concepts to younger students and helped refine the methodology for further use across multiple courses and community events. This project ultimately pursues the establishment of a citizen science initiative, where shipped soil samples will be processed in teaching sessions.

Introduction

Synthetic plastics are remarkable materials that offer desirable properties, such as resistance to corrosion, durability, high mechanical strength, and electrical and thermal insulating capacities; nonetheless, these qualities slow plastic waste degradation (Webb et al., 2013). The cumulative production of plastic has reached 400.3 million tonnes (Plastics – the fast facts 2023, 2025), and its projected production is estimated to reach 1,231 tonnes by 2060. Currently, 1,014 tonnes of such plastic will not be recycled, ending up in landfills, or incinerated, mismanaged, and/or directly leaked into the environment (Organisation for Economic Co-operation and Development (OECD), n.d.). Furthermore, plastic waste accumulation is generating microplastics (Thompson et al., 2004), pieces of plastic ranging from 5 mm to approximately 1 μm in size (Hartmann et al., 2019), which are projected to reach 5.8 tonnes by 2060 (OECD, n.d.) (see Figure 1).

The harmful effects of microplastic pollution on natural ecosystems are now evident (Yadav & Mishra, 2025), and studies connecting microplastic human exposure to public health are growing. Human intake of microplastics can happen in three primary ways: (1) inhalation (Prata, 2018), (2) consumption of contaminated food (Hernandez et al., 2019), and (3) direct skin contact (Hernandez et al., 2017). Recently, literature has reported findings of microplastics in human blood (Leslie et al., 2022) and in bodily fluids such as mucus or saliva (Huang, 2022). In addition, emerging studies link human microplastic exposure to heart-related issues (Siniscalchi et al., 2024).

Historically, microplastic studies have focused on water (Desforges et al., 2014) and air (Wright et al., 2020) samples, leaving terrestrial analysis behind (He et al., 2020), possibly due to soil's intrinsic complexity and heterogeneity (Conklin, 2013). Despite such challenges, the extraction and analysis of microplastics from soil is paramount, since soil is a vital component for life on Earth. Additionally, effectively communicating microplastics research and remediation efforts remains vital. Therefore, we are pleased to present our work on developing and implementing a methodology for extracting microplastics from soil, with a dual focus on academic instruction and community engagement. This initiative enhances multidisciplinary science education and establishes the foundation for a broader citizen science project to connect environmental research with the public.

FIGURE 1. Representative Examples of Microplastics.

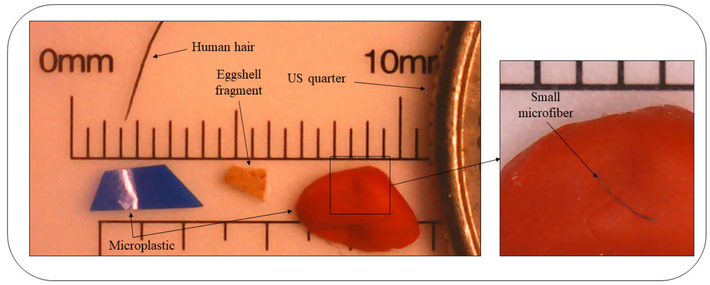
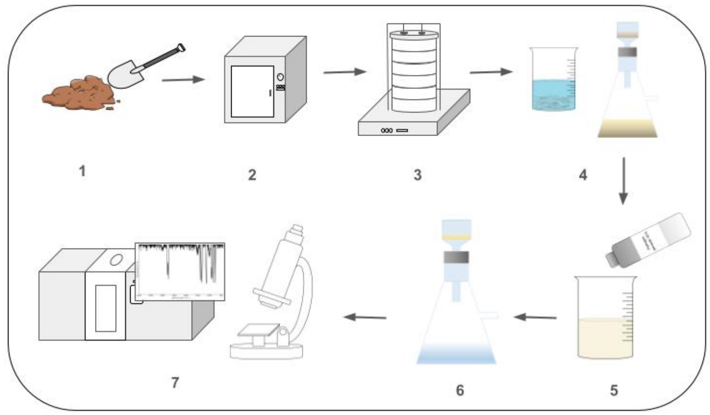


FIGURE 2. Extraction and Analysis of Microplastics



Project Description

Experimental Procedures

The extraction and analysis of microplastics uses non-plastic tools, containers, and lab supplies. The general procedure is represented in Figure 2 (Junhao et al., 2021). It encompasses (1) field sample collection, (2) sample drying, (3) physical separation via mechanical sieving, (4) floatation of light microplastics and filtration, (5) digestion of residual organic matter via chemical treatments, (6) fine filtration microplastics collection, and (7) observation and identification via optical microscopy and advanced instrumentation.

Our student participants collected samples from the banks of the Elm Fork tributaries of the upper Trinity River watershed and a local park. Samples weighed 100 g each and were stored in glass jars inside a cabinet. Before the first session, the soil samples sat uncovered in a drying oven overnight at 75° C. Drying the soil at low heat removed moisture to make it easier to handle and analyze. During the first session, the soil samples were

FIGURE 3. Microscopic Images of Blue Microfibers

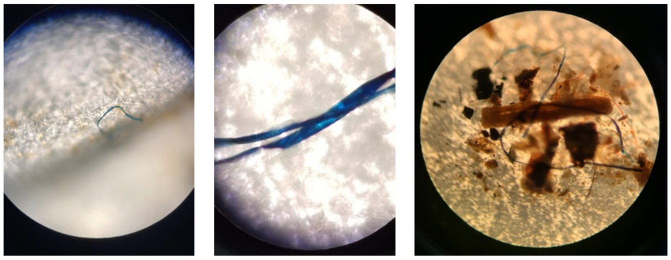


FIGURE 4. Laboratory Session, SCI 3033

crushed using a glass mortar and pestle, then sieved using metal-based meshes and an automatic shaker; the mesh aperture sizes range from 2000–25 μm. Eight-gram subsamples of the smallest particles were transferred to a glass beaker and combined with 100 mL of a saturated calcium chloride solution. This solution helps separate plastic from soil, because many plastics float easily in salty water. The mixtures were gently stirred with a glass rod, covered with a watch glass, and allowed to settle overnight.

In the following session, the mixture was carefully decanted onto a Whatman 40 filter paper set inside a ceramic Hirsh funnel and under vacuum. The portion that passed through the filter—known as filtrate—was transferred to a 250 mL Erlenmeyer flask, mixed with 50 mL of Fenton reagent (Tagg et al., 2017), and allowed to react for one hour. The Fenton process is a chemical treatment based on 30% hydrogen peroxide that degrades organic materials like plant matter without affecting microplastics. Vacuum filtration followed, using a nylon filter with a pore size of 0.25 μm, where small microplastics were collected. Figure 3 shows the microscopic images of the blue microfibers recovered.

Project Implementation

This methodology was first implemented for an interdisciplinary course, SCI 3033, Water in a Changing Environment (Spring 2022). Designed for chemistry and non-chemistry majors, it integrates real-world challenges such as plastic and microplastic pollution into its curriculum through hands-on, collaborative learning experiences. Scheme 1 shows the organizational chart, and the specific roles of all personnel involved in this project.

Gustavo A. Salazar oversaw the overall laboratory procedures while Alana K. Taylor managed personnel logistics. Graduate student Liliana Driver supervised the hands-on implementation of each laboratory technique, while each group of student participants performed the full procedure. This methodology was implemented within laboratory session times and successfully engaged all student participants. See Figure 4 for snapshots of a laboratory session.

A key component of this interdisciplinary approach involved the development of laboratory modules that support collaborative investigation of environmental pollutants. These modules gave students the opportunity to engage in the complete scientific process from literature review to dissemination of findings, while working in

SCHEME 1. Organizational Chart for SCI 3033

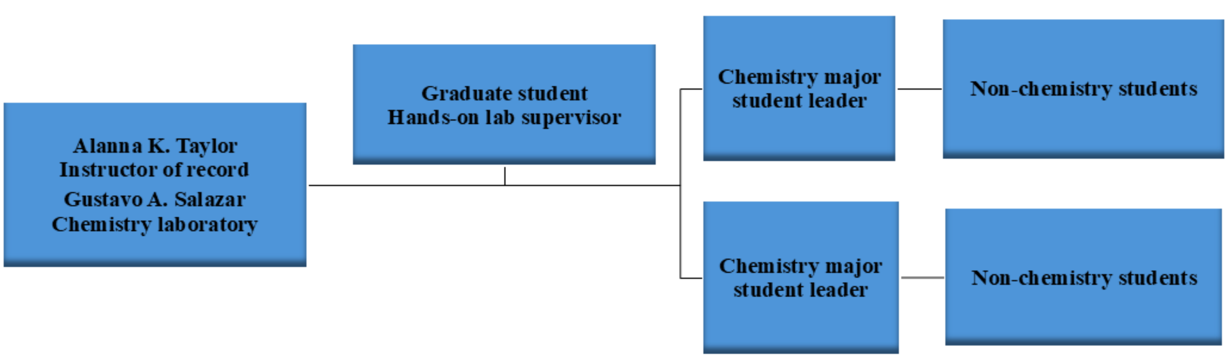


FIGURE 5. Poster Presented at 2022 Student Creative Arts and Research symposium, TWU

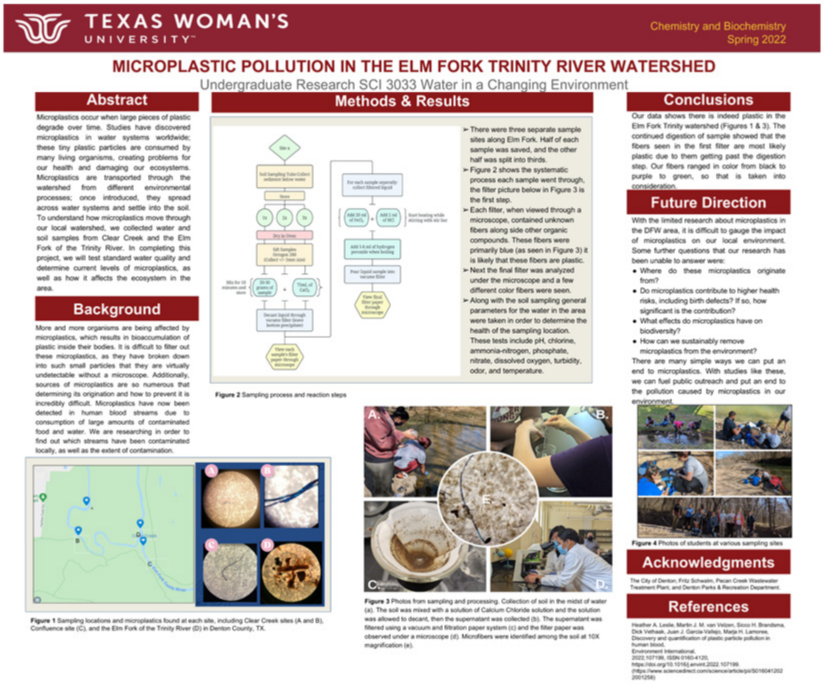


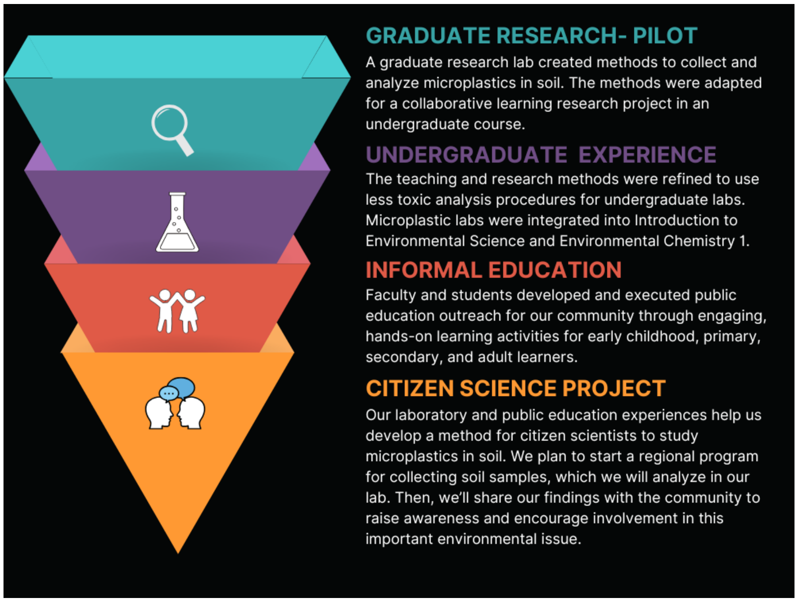
FIGURE 6. Elementary School Students Learn about Plastics in the Environment

team-based settings. As outlined in Appendix 1, students conducted authentic research that included field sampling, laboratory analysis, data interpretation, and public presentation of their work. For example, during week 2 students participated in fieldwork at a local waterway (Clear Creek and Elm Fork of the Trinity River), where they collected soil samples and analyzed water quality. Subsequent weeks' laboratory sessions allowed students to engage in multistep analytical techniques to quantify and characterize microplastic pollution. Students then synthesized their findings into scientific posters, which were presented at the 2022 Student Creative Arts and Research Symposium held at our university (see figure 5).

In parallel with our formal curriculum, we developed informal educational labs and activities designed to reach younger audiences and promote science literacy regarding microplastics and environmental stewardship. This initiative has inspired student-led public outreach and education efforts within the community. For elementary-aged audiences—a Montessori school in our case—we created a microplastic "glitter" lab tailored for second-grade students and scout troops. The informal lesson, "Plastic in the Environment," introduced the young students to basic Earth science concepts, including the Earth's spheres, the water cycle, and the watershed (see Figure 6).

These foundational concepts were used to explain how litter travels through the environment and how plastics and microplastics can infiltrate soil and water systems. The session also covered the fundamentals of plastic materials, the formation of microplastics, and their potential impact on ecosystems. Following the discussion, students engaged in a hands-on glitter lab activity, which modeled microplastic contamination using glitter as a stand-in for microplastic fibers. Each group received a digital scale, digital microscope, two glass petri dishes, a control sample (no glitter), and a prepared glitter-contaminated sample. Students began by forming a hypothesis, then observed both soil samples, first with the naked eye and later through microscopes, recording their findings throughout. The activity concluded with a reflection and discussion where students shared their conclusions based on their observations. The glitter lab allowed young learners to experience the scientific process in a tangible and age-appropriate way while building early awareness of environmental issues related to plastic pollution. To connect classroom learning with real-world science, the presentation concluded with photos of Texas Women's University students conducting fieldwork, analyzing

DIAGRAM 1. Structure of Multidisciplinary Teaching Laboratory



samples in the lab, and presenting their results at a research symposium. This provided the elementary students with relatable role models and a glimpse into environmental research in action.

Discussion

We have implemented an experimental methodology into a multidisciplinary teaching laboratory that successfully isolated microplastics from soil. Chemistry and non-chemistry student participants collaborated and performed all procedures within the teaching laboratory timeframe. Furthermore, student participants and the project members developed educational material and demonstrations for elementary schools and the community in a general setting, laying the foundation for a citizen science project (see Diagram 1).

The SCI 3033 Water in a Changing Environment course provided students with an interdisciplinary platform to examine the complexities of global water issues, emphasizing local environmental concerns. In this course, students developed and delivered an informal environmental education lesson focused on watersheds and the issue of microplastic pollution to children aged four to six at a local Montessori school. Students read age-appropriate books and used hands-on demonstrations, such as building a simple watershed model, to illustrate how microplastics travel through water systems and affect the environment. This effort displayed the students' ability to synthesize course content into engaging, accessible formats for younger audiences while reinforcing their own learning through teaching. Additionally, this experience illustrates how student engagement can bridge classroom learning with community-based microplastic research.

Examples of citizen science projects in microplastic pollution do exist, yet they focus on water bodies (Forrest et al., 2019) or nearby areas (Nel et al., 2020), larger microplastics (Lots et al., 2017; Adventure Scientists, 2024), or a larger geographical area with limited analysis (The Big Microplastic Survey, n.d.; Barrows et al., 2018). Some published methodologies could lead to implementations into citizen science projects (Camins et al., 2020; Scircle et al., 2020; Doyen et al., 2019); however, procedures could become impractical for citizen scientists. Our team is pursuing the development of a simple yet effective methodology that could be reproducible in the teaching laboratory by a diverse population of students and would process shipped samples from citizen scientists. The potential for a citizen scientist to analyze and categorize the characteristics of microplastics in soil is important, since it can lead to a more informed strategy for remediation development. Including students with diverse majors helps to better understand the dynamic between citizens with different career paths.

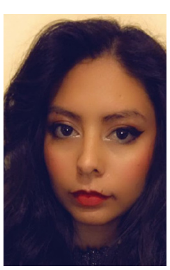
Conclusions and Future Work

A methodology to study microplastics in soil has been developed and implemented in a multidisciplinary laboratory session. This project helped engage a diverse class, connecting chemistry and non-chemistry students. Qualitatively, the first experiments have isolated blue microfibers from samples collected locally. Student participants presented their findings in a university-wide symposium. Student participants also developed simplified adaptations of this methodology for educational purposes at the K–12 level and for the community in general. Finally, we are continuing our efforts to develop logistics for a citizen science project where shipped samples could be analyzed in a laboratory teaching session.

About the Authors

Gustavo A. Salazar is an assistant professor in the Chemistry and Biochemistry division at Texas Woman's University. He received his PhD in Chemistry from the University of North Texas, with a focus in synthetic chemistry and luminescence spectroscopy. He worked on the microwave-assisted synthesis of novel ambipolar polyimine ligands and their tricarbonyl rhenium complexes; he was particularly interested in the photoluminescent phenomenon "luminescence rigidochromism" present in a mononuclear rhenium complex. Salazar has transferred his laboratory and instrumentation experience to Texas Woman's University, where he teaches Environmental Chemistry I and General Chemistry I and II. His current research interests are in microplastic pollution and related topics.

Alana K. Taylor is a lecturer in the Chemistry and Biochemistry division at Texas Woman's University. She is passionate about science and education and has significantly contributed to the field through her innovative teaching methods. She earned her master's degree from the University of North Texas, where she focused on enhancing STEM education for non-majors. Alana recognized the importance of making science accessible to all and concentrated on developing strategies to engage and inspire students from diverse backgrounds. Currently pursuing a PhD in Education and Organizational Leadership, Alana's research interests lie at the intersection of communities, education, and environmental science. Her doctoral work centers on studying community resiliency to climate change, aiming to identify practical solutions for building sustainable and adaptive communities facing environmental challenges.



Liliana A. Driver earned a Bachelor of Science in Biochemistry from Texas Woman's University. Her research focuses on the removal, isolation, and analysis of microplastics in soil using physical and chemical techniques. By employing advanced methodologies, Liliana aims to enhance detection accuracy and develop effective strategies for mitigating microplastic contamination in terrestrial environments.

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LAB: Detecting Microplastics in Soil and Sediment, and Analyzing Water Quality in our Local Watershed

Purpose:

Isolate and quantify microplastics and microfibers from creek soil and water samples collected in the local watershed in order to gain experience performing scientific research, assess local environmental pollution.

Learning Objectives:

- Describe the sources, types, and environmental impact of microplastics in aquatic and terrestrial environments.
- Conduct field sampling of water and sediment in a local watershed according to scientific protocols.
- Apply techniques to isolate and identify microplastics and microfibers in soil and water, using methods such as sieving, density separation, chemical digestion, and microscopy.
- Conduct water quality assessments using portable water testing kits.
- Analyze and interpret environmental data on the presence of microplastics and microfibers and water quality parameters.
- Communicate findings in written and visual formats, including a final research poster.

Project Overview:

Week 1: Introduction & Literature Review

- **Date: Jan. 20**
- **Location: Classroom**
- Activities:
    - Guest speaker (expert in environmental pollution or microplastics).
    - Overview of plastics, microplastics, and local watershed issues.
    - Assign literature review topics; introduce TWU Library database tools.
- Assignments:
    - Literature review summary (due Feb. 10).
- Learning Focus:
    - Understanding sources and implications of plastic pollution.
    - Practicing academic research and synthesis.

Week 2: Field Sampling and Water Quality Monitoring

- **Date: Feb. 3**
- **Location: Clear Creek Natural Heritage Center**
    - Sample locations:
        - Clear Creek
        - Elm Fork
        - Confluence
    - *Store Samples at TWU*
- Activities:
    - Divide into sampling teams (Clear Creek, Elm Fork, Confluence).
    - Collect water and sediment samples.

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    - Conduct in-field water quality tests (pH, turbidity, DO, nitrates, etc.).
- Learning Focus:
    - Hands-on experience with sample collection and environmental fieldwork.
    - Interpreting real-time water quality data.

Week 3: Initial Screening and Density Separation

- **Date: Feb. 17**
- **Location: Chemistry Lab**
- Activities:
    - Dry, grind, and sieve soil samples.
    - Conduct density separation using $ZnCl_2$.
    - Create control samples.
- Learning Focus:
    - Understand and apply principles of physical separation based on particle size and density.
    - Practice contamination prevention methods.

Week 4: Filtration and Microscopy (Part I)

- **Date: Mar. 3**
- **Location: Chemistry Lab**
- Activities:
    - Perform vacuum filtration on the supernatant from the density separation.
    - Visualize solids under a stereomicroscope.
    - Prepare and apply the Fenton reagent to digest organic materials.
- Learning Focus:
    - Master laboratory filtration techniques.
    - Recognize microfibers and microplastics under the microscope.

Week 5: Filtration and Microscopy (Part II)

- **Date: Mar. 24**
- **Location: Chemistry Lab**
- Activities:
    - Final vacuum filtration.
    - Visualize and quantify the remaining microplastics and microfibers.
    - Record and analyze class data.
- Learning Focus:
    - Compare controls and samples.
    - Begin synthesizing the data for the final poster presentation.

Week 6: Poster Session & Reflection

- **Date: Mar. 31**
- **Location: Classroom**
- Activities:
    - Finalize and present research posters.

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  - Group reflections and peer feedback.
- Learning Focus:
  - Scientific communication.
  - Critical thinking on environmental implications and potential solutions.

Poster Guidelines:

Title: Clear, descriptive, and relevant to the local watershed.
Sections:
- Introduction
- Methods (sampling, separation, filtration)
- Results (tables, graphs, micrograph images)
- Discussion (patterns, pollution sources, significance)
- References

Visuals: Required—graphs, photos from field/lab, microscopy images.
Presentation: Present a 5–10-minute summary of work.

Rubric:

Component	Weight
Literature Review Summary	**15%**
Fieldwork Lab Sheet & Observations	**15%**
Lab Notebooks/Worksheets (Lab 3 & 4)	**25%**
Final Filter Analysis and Class Data	**15%**
Final Research Poster	**30%**

Introduction:

Human-made pollution comes in many forms, and one of the most prevalent in modern society is plastic. Plastics are synthetic or semi-synthetic organic polymers used in numerous ways in modern society. From the packaging at the local grocery store to the clothes we wear and the toys that many of us grew up playing with, we are surrounded by plastics. The affordability, versatility, and water imperviousness of plastic polymers provide much of their appeal. They are typically made from petroleum products, with repetitive carbon-carbon and carbon-hydrogen bonding patterns punctuated by cross-linkable functional groups (see Figure 1, which shows the structural formulas of polyethylene [bottom] and polyester [top]).

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However, other types of polymers can also be made from more renewable, biological materials, such as cellulose. Plastic materials are remarkably resistant to biodegradation upon exposure to a wide variety of conditions. This is one of the primary advantages of plastics from both a manufacturer's and consumer's perspective, but also a significant disadvantage in terms of environmental sustainability. For example, most plastics do not dissolve in water, and many are also impervious to strong acids, bases, and oxidants. Plastic materials tend to persist in one form or another in the environment for a very long time. Although pure plastics are usually biologically inert and are considered non-toxic to living organisms, many compounds that leach from plastics during their breakdown are carcinogenic or endocrine disruptors, and other toxic environmental pollutants tend to "stick" to plastics in the environment.

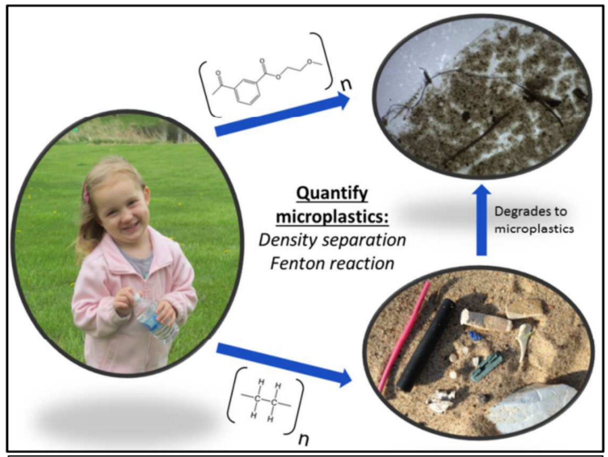

Figure 1: Plastics, such as polyethylene, are used in many items such as water bottles. These large items can degrade into smaller and smaller pieces, eventually yielding microplastics with a diameter of less than 5 mm. Many fabrics, such as the fleece jacket shown on the child in this figure, are made of polyesters. These polyester fabrics shed a great deal of plastic microfibers during their wear and washing.

Although plastic pollution, especially in waterways and oceans, has been studied for years and is well known to many people, a lesser-known problem is microplastic pollution. **Microplastics are plastics less than 5 mm in diameter and are a class of emerging pollutants of concern due to their widespread presence in water and soil.** Their effect on ecosystems and food chains is largely unknown, but a variety of organisms readily ingest them. Although microplastics have been around for decades, it is only recently that many research groups have established their ubiquitous presence in waterways, oceans, and surrounding areas.

Microplastics come from primary and secondary sources and include both particles and microfibers. Primary microplastics are intentionally produced small-sized microplastics that are added to personal care products and as industrial scrubbers (this addition to products began in the 1990s), whereas secondary microplastics form from the degradation and fragmentation of larger plastic items. Regulatory efforts are already underway to curb the use of primary microplastics, with legislation such as the Microbead-Free Waters Act of 2015 being enacted in the United States. States are making efforts to diminish microplastic pollution in the future.

A thorough understanding of where microplastic pollution is coming from is currently not complete. **This laboratory experiment will focus on isolating and quantifying microplastics found in soil and water from our local watershed, Clear Creek and the Elm Fork tributary of the Upper Trinity River** (Figure 2).

This lab will analyze how many microplastics are being retained in the creek soil and the adjacent water quality. During sampling, water quality will be monitored using a water quality kit. In the laboratory, samples collected will be dried, ground, sieved, and separated according to density, and digested and filtered in order to isolate microplastics from the natural materials. These microplastics will then be visualized with a

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stereomicroscope and quantified in terms of microplastics and microfiber size, shape, and color. Students will compare and plot samples, and after tabulating their results will assess whether or not the sampling sites are a significant source of microplastics.

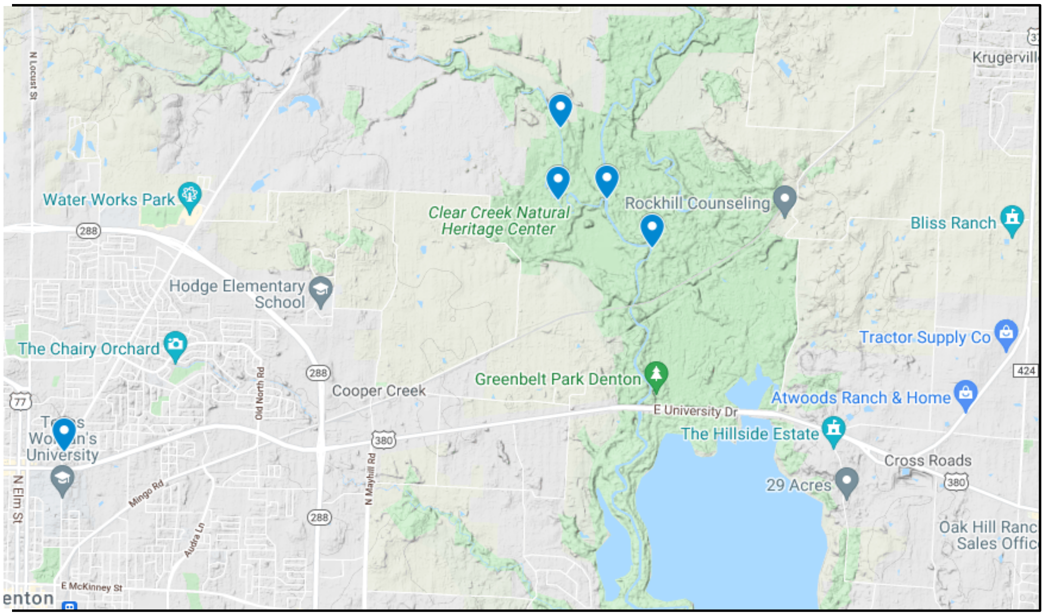

Figure 2: Sampling Site, blue unlabeled markers indicate sampling site. Map created on Google Maps.

Assignments + Procedures:

Jan. 20, Lab 1: Begin Microplastic Research Project

- ➢ Guest Speaker
- ➢ Discussion
- ➢ Overview of project
- ➢ Begin Literature Review

Project Planning

- **Literature Review:** As a class, we will be compiling a literature review. Individually, choose one topic to write a two- to three-paragraph summary on. Use the TWU Library electronic database to find your articles. *If you need assistance finding a paper to read, you can contact Suzi Rumohr, our content librarian.* Be sure to cite your sources and references. ***The summary is due on February 10 as a discussion post in Canvas***.
    - Literary Review Topics:
        - Microplastics
        - Bioaccumulation (of microplastics)
        - Water Quality
        - Local Watershed (Upper Trinity)
        - Microbead-Free Waters Act of 2015
        - *A topic of interest to you (but still related to the research project/investigation).*

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- *How to write a summary*
- *What is a Literature Review?*
- *How to write a Literature Review (we will do this as a class).*

Feb. 03, Lab 2: Fieldwork: Clear Creek Natural Heritage Center

- Collect Samples + Fieldwork:
  - Sample locations:
  - Clear Creek
  - Elm Fork
  - Confluence
- Store Samples at TWU
- Fieldwork Lab Sheet

Collect Samples + Water Monitoring at Various Locations.

As a class we will split into groups to collect soil and water samples and to collect data from our sample sites. The locations we will be collecting from are Clear Creek, Elm Fork, a tributary of the Upper Trinity River, and the point where they converge together aka the Confluence. *Click this link to see a map of our sites.*

Procedures:
During all procedures be sure to record important observations on your Lab Sheet.
Collect Samples and Water Quality Test

Purpose: Collect sample water and soil samples for use in the lab and perform water quality testing on-site. Test the water for chlorine, pH, nitrates, phosphates, ammonia, dissolved oxygen, and temperature.

Materials:

- 120 cm Turbidity Tube
- LaMotte Water Pollution Kit
- Glass jars
- Phone with a camera

Step 1: Collect Soil + Water Samples
Throughout the procedure, ensure your hands are clean, keep clothing away from samples, and cover materials as much as possible to reduce contamination. All glassware should be cleaned with deionized or filtered water before going to the field.

1. Take a picture of your site and record your observation on your Lab Sheet.
2. You will collect a water and a sediment sample for your site. Obtain glass jars to collect the samples.
3. Record the location of your site on the jar.
4. Carefully pack the sample to take back to the laboratory.

Checkpoint: At this point, you should have one sample of sediment and one sample of water.

Step 2: Water Quality Test
1. Get a turbidity reading using the turbidity tube.

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2. Follow the directions on the LaMotte Water Pollution Kit and test for chlorine, pH, nitrates, phosphates, ammonia, dissolved oxygen, and temperature.

Checkpoint: At this point, you should have data for your site.
Disposal: Follow the guidelines outlined in the LaMotte Water Pollution Kit.

Feb. 17, Lab 3: Initial Screening and Density Separation

- ➢ Chem Lab: Screening + Density and Filtration + Visualization
- ➢ Lab Sheet

Initial Screening and Density Separation

Introduction:
The first step in this laboratory is to pulverize and separate particles by size in dried soil using sieves, which are available with different pore sizes. The soil you will use has been dried in an oven before use for accurate mass determination and to facilitate the sieving process. Wet, muddy soil will not pass through the sieves easily. A mortar and pestle is used to break up the soil particles into fine pieces, as this low level of mechanical force is unlikely to break up any microplastics. The larger particles will not be analyzed because this laboratory is focusing on microplastics analysis, which by definition must be smaller than 5 mm in diameter.

Following this sieve separation, transfer a 20–30 g sample of the dried, sieved soil into a 250 mL beaker and use the density of the microplastics as the next means of separation from the natural materials. Recall that density is equal to mass/volume, and different substances have different densities. Pure water, for example, has a density of 1.0 g/mL. Anything with a density less than 1.0 g/mL, such as Styrofoam or oil, will float on water. In contrast, anything with a greater density than 1.0 g/mL will sink in water (such as a piece of lead or honey). Many plastics float in water, indicating a density of less than 1.0 g/mL. However, the density of some plastics falls within the range of 1.0–1.3 g/mL and they will therefore sink in water. We will create a solution with a density of around 1.3 g/mL to ensure that all the microplastics float or suspend in the solution and can be separated from heavier solid particles.

Throughout this lab, it is important to keep your solutions and filter paper covered. The reason for this is to reduce contamination of your samples, since microfibers are ubiquitous and readily shed from certain types of clothing. For Part A, you will complete the mechanical sieving process of your soil and the density separation. For Part B and in the following weeks, you will filter the liquid portion of your solution, visualize the components present on the filter paper using a stereomicroscope, and degrade the natural components in your sample using the Fenton reagent. Lastly, you will again filter the liquid portion of your sample and use a stereomicroscope to visualize and quantify the number of microplastics and microfibers found in your original sample.

Procedures:
During all procedures, be sure to record important observations on your Lab Sheet as the experimental steps are proceeding.

Screening of soil samples and density separations

Purpose: Isolate soil that has a soil particle size of less than approximately 5 mm using a sieve. Separate solid particles with a density of 1.3 g/mL and lower from heavier particles using density separation and a solution with a density of approximately 1.3 g/mL.

Materials:

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- #4 sieve (4.75 mm)
- hot plate
- scoopula
- mortar and pestle
- 2, 150 mL beaker
- 2, 250 mL beakers with lids/watch glass (or foil)
- zinc (II) chloride tetrahydrate
- 10 mL graduated cylinder
- magnetic stir plate with magnetic stir bar

Step 1: Screening of soil.
Throughout the procedure, ensure your hands are clean, keep clothing away from samples, and cover materials as much as possible to reduce contamination. All glassware should be cleaned with deionized or filtered water.

1. You will use oven-dried soil samples. Obtain approximately 40 g of the dried soil using a clean 150 mL beaker from either sample A or B, and determine its mass. Be sure to record the mass of the beaker before adding any soil. Record the exact mass and your sample location in your Lab Sheet. Cover the beaker.
2. Transfer the soil to a mortar and pestle, and pulverize it to break up clumps of dirt and other materials.
3. Sieve the 40 g soil sample and collect the soil with particle sizes of approximately 5 mm or smaller into a 250 mL beaker. Soil with particle sizes below 5 mm is the soil that goes through the sieve. Keep the sample covered as much as possible with foil, and keep your clothing away from the sample.
4. If some clumps maintain integrity throughout the separation process, remove the soil from the sieve into a mortar, and use the pestle to break up the clumps. Add the ground soil back into the sieve and repeat the process.
5. Transfer 20–30 g of your soil to a clean 250 mL beaker and cover it with a lid. Record the exact mass of the sieved soil in the beaker on your Lab Sheet, making sure to record the mass of the beaker before adding the soil. Record this mass of dry soil on all Lab Sheets, as you will need it for your final analysis.
6. At this point, create a sample control (or blank) by obtaining a clean 150 mL beaker. Cover the beaker with foil or a watch glass, just as you did with the beaker containing the soil.

Step 2: Density separation.
1. Prepare 100 mL of a 3.6 M $ZnCl2$ solution, which will create a solution with a density of 1.2–1.3 g/mL. Use a clean 150 mL beaker to prepare this solution and keep it covered as much as possible. Record your calculations on your Lab Sheet. If the solution does not dissolve immediately, add a magnetic stir bar to the beaker, place it on the magnetic stirrer, and stir the solution until the solid has completely dissolved. If after 10 minutes of stirring, your solid has still not fully dissolved, transfer the beaker to a hot plate for a few minutes.
2. Test the density of 5.0 mL of the zinc chloride solution. Add 85 mL of the zinc chloride solution to your 250 mL beaker containing the sieved soil, and pour the last 10 mL into the control beaker. To test the density, remember that $d = m/v$, and the units of density are typically g/mL. Therefore, use a 10 mL graduated cylinder to obtain 5.0 mL of the zinc chloride solution. Then, determine the mass of this solution in grams by weighing the graduated cylinder before and after adding the 5.0 mL of zinc chloride solution. Record your calculations on your Lab Sheet.
3. Add a clean magnetic stir bar to the soil and mix it with the zinc chloride solution. Using a magnetic stirrer, stir the solution thoroughly for 10 minutes, keeping it covered with foil as well as possible. Remove the stir bar from the solution when you are finished.
4. Clean the stir bar and add it to your control beaker. Stir the solution in the beaker for a minute, and then remove the stir bar. Keep the beaker covered as much as possible.
5. *If needed, store both beakers:* the one containing the soil and zinc chloride solution, and the control beaker. Make sure they are covered.
6. Clean the stir bar, mortar, pestle, and sieve, and rinse each with deionized water.

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Checkpoint: At this point, you should have one beaker of sieved soil in a 3.6 M zinc chloride solution covered with foil and a covered control beaker.
Disposal: All soil that is not placed in a 250 mL beaker can be disposed of in the regular garbage.

Mar. 03, Lab 4: Filtration and Microscopy (Part I)

- ➢ Chem Lab: Vacuum Filtration
- ➢ ASSC 267: Stereomicroscope
- ➢ Lab Sheet

Introduction:

The soil solution will be filtered to separate the solids that are suspended or floating in the liquid from the solids at the bottom of the beaker. We will use a method of filtration called vacuum filtration to collect microplastics and other particles with a density of less than 1.3 g/mL on a piece of filter paper. We will use a nylon filter membrane to collect the microplastics in this step, which is resistant to the strong oxidant used in this procedure. The filter paper, which will contain any microplastics and a variety of other materials at this point, will then be viewed using a stereomicroscope.

This filter paper will then be transferred to another beaker, and the contents will be oxidized to remove natural material. Since natural substances, such as plant materials and cotton fibers, may still be present at this point, the next step is to digest these natural fibers using an oxidant. An oxidant is a substance that removes electrons from different species during a redox reaction. The oxidant is formed from the Fenton reagent, which works best at a pH of 2–3 and can digest a wide range of organic molecules, macromolecules, and macroinvertebrates. Plastics, however, are not digested or decomposed by this oxidation process.

In the Fenton reagent reaction, ferrous iron (Fe2+) is added to a solution of hydrogen peroxide, and iron (II) acts as a catalyst for the production of a strong oxidant that can oxidize various organic matrix compounds in the solution. More specifically, this reaction creates many free radicals, which are powerful and non-selective oxidants, as shown below, where the dot after a chemical formula represents a free radical. This reaction is highly exothermic and has been used over the years to oxidize contaminants in soil or wastewater.

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + HO^{\bullet} + OH^-$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + HOO^{\bullet} + H^+$$

The HO• and HOO• are the free radicals that react with and digest the organic matrix present in the sample. These secondary reactions often have water and carbon dioxide (gas) as a product, which is why you can see a great deal of "foaming" or "bubbling" during this reaction, as this is the carbon dioxide gas escaping the solution. You will store your oxidized filter paper until next week, at which point you will re-filter your solution and visualize your filter paper one last time.

Procedures:

During all Part B procedures, be sure to record important observations on your Lab Sheet as the experimental steps proceed.

Filtration and visualization followed by Fenton reagent exposure to digest natural material.

Purpose: Isolate the floating and suspended particles by decanting and filtering. View the filter paper under the microscope. Subject the collected solids to the Fenton reagent to digest the natural materials.

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Materials:

- hot plate with a magnetic stirrer and stir bar
- vacuum filtration apparatus
- 30% (v/v) hydrogen peroxide
- 0.0075 M FeCl2 solution
- 0.1 M HCl
- glass stir rod
- forceps
- 10 mL and 100 mL graduated cylinder
- squirt bottle with deionoized water
- pH paper
- nylon filter paper, .45 µm–5 µm pore size

Step 1: Filter the liquid and visualize the filter paper.

1. Obtain your soil/solution mixture, but take care not to disturb it! You want to keep the solids on the bottom of the beaker and the liquid on the top separate. Carefully remove it from your lab drawer and do not shake it unnecessarily. You will pour out the liquid portion into a vacuum filtration filter fitted with a piece of nylon filter paper. Your instructor will help you with this vacuum filtration step. This process is called decanting the liquid.
2. When your liquid mixture is almost gone, stop decanting to ensure that you don't add the solid to your filter paper. Use a water squirt bottle to rinse any solids that have stuck to the insides of the filtration cup onto the filter paper.
3. Shut off the vacuum. Remove the glass top from the vacuum filtration setup and break the vacuum by unplugging the vacuum hose, if necessary. Using tweezers, remove your filter paper from the funnel and put it on a watch glass. Add a second watch glass to the top of your original watch glass as a cover for your filter paper. Be sure to flip the covering watch glass so that the glass does not compress the sediment on the filter paper.
4. Thoroughly rinse the filter funnel and filter holder, and vacuum filter the contents of the control beaker. Follow the same procedure for rinsing the filter and removing the filter paper. Use a new filter paper for the control beaker.
5. View each filter paper under the magnification of the stereomicroscope and record your observations. Try to identify microfibers or microplastics in your samples. Some samples may not contain any microplastics or microfibers at all. You must remove the cover watch glass before microscope visualization.

Step 2: Subject the material on your filter paper to the Fenton reagent to degrade natural materials.

The following steps should be completed under a fume hood, wearing gloves and goggles, due to the use of concentrated hydrogen peroxide and the potential for rapid gas production.

1. Transfer each filter paper to a 150- or 250-mL beaker and add 2 mL of 0.1 M HCl and 20 mL of 0.0075 M FeCl2 solution to the beaker containing the filtered sediment. To the control beaker, add 1 mL of HCl and 10 mL of 0.0075 M FeCl2 solution. Stir the contents of each beaker slowly with the magnetic stir bar to avoid damage to the filter paper. The pH should be 2–3. Test the pH with pH paper after adding the HCl and FeCl2 and allowing the solution to stir for approximately 1 minute. If the solution is not acidic enough, add HCl dropwise with stirring, checking the pH after every few drops, until a pH of 2–3 is reached.
2. Begin warming the mixture on a hot plate under the hood. The mixture should only be heated to about 70 °C, not to boiling! Carefully, use a thermometer to monitor the liquid's temperature. If the temperature goes above 70 °C then remove your beaker from the hot plate, turn down the temperature of the hot plate, and wait for it to cool down. While heating, slowly add 5–6 mL of 30% hydrogen peroxide (H_2O_2) to the sediment mixture. Add 3 mL of the H_2O_2 to the control beaker. It takes several minutes for the reaction to reach its maximum reactivity. The maximum reactivity is determined by maximum "foaming."
3. Keep a bottle of deionized (DI) water nearby. If the reaction begins to froth excessively, to the point where it may spill over the sides of the beaker, remove the beaker from the heat and add DI water to calm the reaction. After adding all the hydrogen peroxide, continue stirring for an additional 15 minutes. If you use it, remove the magnetic stir bar before storing

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your solution. After the foam has subsided, use the markings on the side of your beaker to determine and record the volume of the final solution on your Lab Sheet. Cover each beaker with foil and store them until next week.

Checkpoint: The Fenton reagent reaction needs to be complete (no more bubbling) before you can store your solution. Make sure the beakers are covered with foil or a watch glass until next week.
Disposal: Leftover liquid from the Fenton reagent exposure may be discarded into the container labeled "Zinc Chloride Waste" in the hood. Soil solution and Fenton reagent solution that you no longer need to use can be disposed of in the regular garbage, but solid soil should not be disposed of directly down the drain as it may cause plumbing blockages.

Mar. 24, Lab 5: Filtration and Microscopy (Part II)

- Chem Lab: Vacuum Filtration
- ASSC 267: Stereomicroscope
- Lab Sheet

Introduction:

After the Fenton oxidation reaction last time, there should not be any natural fibers left in the solution that will confuse your microscopic identification of microfibers and microplastics. This week the solution will be filtered again using vacuum filtration, and you will then view your filter paper using the stereomicroscope and analyze the microfibers and microplastics. You will identify the microplastics and microfibers on your filter paper. The larger chunks of microplastics will usually be more obvious to identify, but microfibers also have a characteristic appearance shown in Figure 2.

Figure 2: Image showing microfiber on a filter paper that was processed similar to your filter paper. The microfiber has a distinctive appearance, compared to the fragmented organic matrix (red arrow points at microfiber).

You must move your filter paper through the viewing area of the microscope to analyze the entire area of your filter paper. Depending on where your soil sample was taken, you may or may not be able to identify microfibers. Count and record the number of microfibers and microplastics you find. This visual inspection of samples is what researchers currently use to assess microplastic and microfiber contamination in both soil and water samples. An additional confirmation step that is often performed, which we will not do in this lab, is subjecting the larger particles to a spectroscopy technique after visual identification. This technique can confirm that a particle or fiber is in fact plastic and can identify the specific type of plastic by exploiting the fact that different chemical compounds and polymers will absorb different wavelengths of the electromagnetic spectrum in a way that is characteristic of that specific compound or material.

Procedures:

During all procedures, be sure to record important observations on your Lab Sheet as the experimental steps are proceeding.

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Second vacuum filtration to isolate particles and final microscopic viewing.

Purpose: Final filtration to isolate the synthetic particles and identify and count the number of microplastics and microfibers remaining on your filter paper using a stereomicroscope.

Materials:

- vacuum filtration apparatus
- nylon filter paper, 0.45 μm–5.0 μm pore size
- stereomicroscope
- forceps
- water wash bottle

Step 1. Vacuum filtration

1. Use a water wash bottle to clean off the filter paper, and then, using forceps, remove it from the beaker. If your filter paper is still intact, you can reuse it by adding it to the funnel of the vacuum filter apparatus. If your filter paper is not still intact, wash off the remaining pieces of the old filter paper with the water bottle and discard them. Use a fresh nylon filter in the vacuum filtration apparatus if your original filter paper must be discarded. Pour the liquid mixture from the beaker into the vacuum filter funnel to collect the solid particles that remain after exposure to the Fenton reagent. Rinse your beaker with deionized water and add the rinse to the filter funnel. Repeat if some of your mixture remains in the beaker. Rinse the inside of the vacuum cup to remove any solid material stuck to the inside of the vacuum cup onto the filter paper using DI water in a squirt bottle. Your instructor will help you with the vacuum filtration process.
2. Shut off the vacuum. Remove the glass top of the vacuum filtration set-up and break the vacuum by unplugging the vacuum hose if necessary. Your instructor will help you with this part. Using forceps, remove the filter paper from the funnel and place it on a watch glass or a petri dish. Add a second watch glass to the top of your original watch glass as a cover for your filter paper, flipping the top watch glass so that it does not compress the filter paper on the bottom watch glass.
3. Repeat the above procedure for the contents of the control beaker, keeping the control filter paper on a separate watch glass.
4. View each filter paper under the stereomicroscope's magnification and record your observations.

Step 2. Stereomicroscope observations

1. View all parts of your filter paper using the stereomicroscope, counting and recording the number of microplastics and microfibers on each part. Record these numbers and sketch the shapes on your lab report.
2. Carefully place identified microplastics into a small vial if you can remove them from the filter paper with tweezers.
3. On the class board, record the total number of microplastics and microfibers you found in your sample, and where your sample location site was. Also share the initial mass of the dried soil you tested (this value was determined in the first week, and should be between 20–30 g). Also, record the number of microfibers or microplastics present on the filter from your control sample.
4. Collect the entire class data to complete questions on the Lab Sheet.

Disposal: All filter papers may go in the regular garbage, and the beakers can be rinsed in the sink.

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Exploring Interdisciplinary Co-Curriculum Service-Learning Through a Student-Formed Consulting Community

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Abstract

A campus-wide student-formed consulting community provides an interdisciplinary co-curriculum service-learning opportunity that connects students from various disciplines across a Midwest university to work on sustainability challenges in the local community. Projects include using waste glass in construction materials, cutting carbon footprint by a lighting retrofit, using a rain garden for stormwater runoff, and beneficial use of dredged materials. The real-world impact truly engages and excites students; taking action and serving the local community gives them a strong sense of connection to that community. Students also gain in their professional skills development, particularly in the areas of taking initiative, collaborating in a teamwork environment, problem solving, and communication/presentation skills. Faculty mentors consider this not only as a great experiential learning and civic engagement opportunity, but also an opportunity to collaborate with faculty in other disciplines, and some have extended service-learning projects to interdisciplinary research and grant opportunities. Challenges and lessons learned are also discussed.

Introduction

Service-learning is one high-impact educational practice (Kuh, 2010) that engages the student, university, and community in learning through authentic situated experiences, where individuals learn through participation and engagement (Fenwick, 2003). Steiner and Watson (2006) critically examined the implementation of service-learning in business education, highlighting a disconnect between the intended civic and ethical objectives of service-learning and its actual application in business curricula. It was found that nearly half of the courses treated service-learning projects as standard assignments, with only 18% explicitly emphasizing civic responsibility and community involvement in their objectives. Steiner and Watson (2006) reported that for service-learning to fulfill its potential in fostering civic engagement and ethical awareness, educators must clearly articulate and promote course objectives that integrate these values.

Service-learning is usually offered in the context of a single course, because "academic work traditionally segments knowledge into specific disciplines. . ." (Culhane et al., 2018). While the benefits of an interdisciplinary education that shapes well-rounded individuals who can think critically and solve complex, multidisciplinary problems are being recognized by many institutions of higher education (Lindvig et al., 2019; Culhane et al., 2018; Godemann, 2006; Zeppos, 2018), examples of interdisciplinary service-learning in the literature are typically between two disciplines or in a capstone course taught by instructors from two disciplines (Hill & Yazici, 2013; Marx et al., 2021; Culhane et al., 2018), with fewer involving more than two disciplines (Brassler ,2018; Marshall, 2013). In a study conducted by Zlotkowski (1998), a collection of case studies from diverse disciplines showcasing successful models of service-learning were summarized. This study provided replicable examples and inspiration for structuring a program with strong interdisciplinary emphasis.

Service-learning opportunities can also be implemented in co-curricular settings where community engagement is not bound to a particular course. Participation in these activities is not credit driven, as students voluntarily participate in a community engagement that is not integrated into their regular course of study (Judge et al., 2011). Co-curricular types of service-learning provide meaningful experiential learning experiences with widely reported positive learning outcomes, including a student's growth in academics, social maturity, critical thinking, communication, collaboration, and leadership skills (Saddiky, 2020; Bakar & Esa, 2017; Keen & Hall, 2009). While the values and benefits of applying an interdisciplinary approach to co-curricular service-learning are recognized (Bloomquist et al., 2022), such programs reported in the literature are scarce. Notably, an innovative interdisciplinary service-learning program that compliments the curriculum has been reported by University of North Carolina School of Medicine at Chapel Hill. In this program students who majored in seven healthcare disciplines—medicine, nursing, occupational therapy, pharmacy, physical therapy, public health, and social work—volunteered to provide monthly home visits to isolated, elderly individuals in the community with complex medical and social issues (McWilliams et al., 2008).

This article describes our exploration of an interdisciplinary co-curricular service-learning program in which no academic credits of any kind are earned. This program aims to enhance civic engagement and help students develop professionally though a student-formed consulting community. Faculty and staff from across the university have encountered many service-learning opportunities that require interdisciplinary collaboration, yet there is no mechanism within the university to implement them. In the meantime, it may be difficult for students to find a high-quality internship, often because of a lack of prior professional experience. This program presents an opportunity to address both issues. In this article, we describe the logistics of the program and present a few examples of community sustainability projects completed, feedback from students and clients, challenges and lessons learned. In conclusion, we discuss what we plan to do going forward.

This student-formed consulting community, the Innovative Consulting Community (ICC), is made up of Illinois State University (ISU) students and mentors and provides solutions to local for-profit and not-for-profit sectors. The ICC provides a mechanism to connect students across campus, from various disciplines, to work on real-world clients' problems, while giving students the opportunity to further develop a creative mindset and to propose solutions to complex problems using innovative strategies. The program is university wide, drawing students and faculty mentors from across disciplines to serve real-world clients from the surrounding community. Students from all majors and any grade level are welcome to participate. The program's interdisciplinary nature successfully draws together students and faculty mentors from over 30 academic majors across the ISU campus, including the disciplines of business, music, theatre, dance, interior design, nursing, political science, public relations, psychology, foreign language, English, sociology, computer science, biology, geology, environmental science, agriculture, and education, to consider projects such as employee retention, providing fresh produce to students, sustainability practices, and marketing to millennials in the local community.

In the spring and early summer, projects are identified, scoped, and posted on the ICC website. The ICC website layout and content were tested with university alumni, who provided valuable feedback before the site went live. Projects are identified mainly by alumni, faculty, networking on LinkedIn, various university weekly email updates, social media of alumni and faculty, and word of mouth. After projects are identified, mentors with relevant backgrounds are identified and asked to participate.

At the beginning of the fall semester, students are introduced to projects through the ICC website. Each project has a detailed description. Marketing of the ICC website is mainly done through advertisements in the university's student newspaper, invited talks during the student association meetings, educating career and academic advisors who have close contact with students about the benefits of the ICC, and personal emails from the ICC faculty coordinator to students whose majors or fields of study are aligned with projects. Typically, there are four to six students working on a project and three or four mentors from relevant disciplines who provide technical guidance to these students. Student teams select a project manager, then function as a consulting team to achieve the project goals. In the fall semester, students complete a series of online learning modules available through the university's learning management system (LMS) to help prepare them for the consulting experience. These online learning modules offer fundamental training in leadership, project management, design thinking, and how to work as a team and be effective as a team. Students complete the modules on their own time, without receiving course credit, and are graded on a pass or fail scale. Following successful completion of the modules, students spend months researching and fine-tuning recommendations for the organizations. Faculty mentors serve as student team guides rather than supervisors and are expected to meet with student teams once every two weeks in the spring semester. The faculty mentors help the student teams follow a design-thinking model: define and understand the problem; develop an array of solutions by engaging with users/clients to fix the problem; and finally, pick the best of those solutions through testing, analysis, and experimentation.

At the end of the spring semester, students present their findings/solutions to the clients with an oral presentation and a final technical report. The time commitment in the fall semester is approximately 15 hours (total, not per week) and the spring semester time commitment is approximately five hours per week until mid-April.

ICC Sustainability Projects

In this article, we present a few ICC projects that focus on environmental sustainability, such as beneficial use of waste glass, cutting carbon footprint through lighting retrofit, and other sustainability practices in the local community. Universities play a unique role in addressing climate change and creating a sustainable society, by demonstrating best practices, researching solutions to real-world problems, educating future communities and leaders, and promoting sustainability (Barth et al., 2014; Evans et al., 2015; Ralph & Stubbs, 2014). Specifically, students working on the projects presented in this paper majored in environmental health and sustainability; construction management; geography, geology, and the environment; conservation biology; agriculture; and business.

Waste glass to construction material

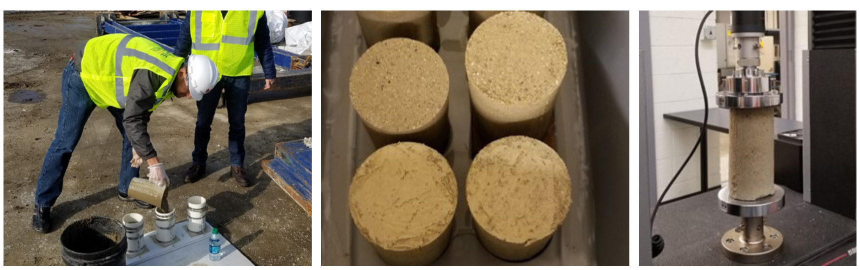
This project involves working with a local single-stream recycling company. Their recycling process produces a broken glass material that is difficult to recycle because of mixed color, contamination, and small size (Figure 1). The company is losing money from glass recycling and

FIGURE 1. (a) Stockpile of Waste Glass at Local Recycling Facility
(b) Sieved Portions of Cleaned Crushed Waste Glass Obtained from Local Recycling Facility

1a **1b**

FIGURE 2. Students making and testing flowable fills samples with cleaned and grounded waste glass powder (a) application of flowable fill in the field; (b) cleaned and grounded waste glass powder coarse (left) and fine (right); (c) flow test; (d) making flowable fill specimen for strength test; (e) dried flowable fill specimen for strength test; (f) strength test

2a **2b** **2c**



2d **2e** **2f**

will stop the glass recycle program unless they can find a market for the waste glass.

Our students proposed that broken glass be used in construction material, specifically in Controlled Low Strength Material (CLSM), also known as flowable fill, which is widely used for non-structural purposes such as backfill or road bases (Figure 2a). Recycled Glass Powder (RGP) is well known as an effective pozzolan in concrete and in many applications is equal or superior to conventional Portland cement or its alternative such as fly ash, if milled to <50 µm (Dyer & Dhir, 2001; Shi et al., 2005). Using waste glass powder as a partial replacement for cement is a sustainable practice, as it cuts carbon and toxic pollution associated with manufacturing cement (Islam et al., 2017; Jani & Hogland, 2014). The cement industry is the third largest source of industrial pollution, emitting more than 500,000 tons of sulfur dioxide, nitrogen oxide, and carbon monoxide per year (USEPA, 2024a).

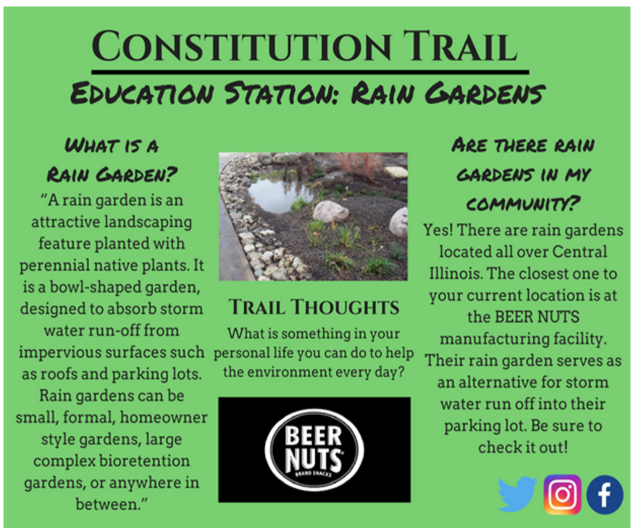
Students worked with local concrete companies to make flowable fill concrete using waste glass and test its properties (Figure 2b–2f). Students also worked with the local public works department to determine the annual demand for this type of concrete and proposed this to the recycling facility.

Lighting retrofit to cut carbon footprint

This project serves our local snack brand, BEER NUTS®. They are hoping to cut their carbon footprint, eliminate mercury exposure, reduce cost, and improve the productivity of their employees through a retrofit of their lighting system. Currently the company is using florescent lights, which contain mercury. Lighting is one of the largest uses of electricity in the facility, contributing to the plant's carbon footprint as well as its operating costs. To reduce both costs and greenhouse gas emissions, the company retrofitted the plant several years ago with more efficient fluorescent lighting. However, recent improvements in LED (light-emitting diode) lighting offer an option even more efficient than fluorescent lighting (USEPA, 2017). In addition, because fluorescent lights contain mercury, they must be recycled at a significant cost, and the presence of mercury-containing equipment in a food production facility is always a concern. Therefore, replacing fluorescent lights with LED lights could have a number of benefits for the company and the environment (Hoang et al., 2020; Shahzad et al., 2015; Souza et al., 2019). After a detailed tour (Figure 3) and energy audit of the facility, students conducted a thorough analysis of the bulb options, replacement costs, maintenance, recycling regulations, and incentives offered

FIGURE 3. Students and CEO of Beer Nuts (first from the left) after touring the facility.

FIGURE 4. Educational Sign Outside Rain Garden



by local energy suppliers. Then, the team came up with three retrofit scenarios for the facility. For each scenario and each sub-option, students calculated and presented energy savings, greenhouse gas emission reductions, cost savings, and other financial metrics. The team provided their recommendation for the best option, and the company has implemented the team's recommendation.

Rain garden for storm water management

BEER NUTS® is also looking for a way to minimize storm water runoff from their property and the associated storm water fee. In addition, precipitation surge in parking lots that freeze during the winter has been a terrible fall hazard for their employees and customers. Our students proposed using a rain garden to address this problem. A rain garden is an attractive landscaping feature planted with perennial native plants to slow runoff, encourage infiltration into the soil, reduce flooding, and reduce storm water fees (Asleson et al., 2009; Ishimatsu et al., 2017; Sharma & Malaviya, 2021). Based on the roof and parking lot area and local weather conditions, several local landscaping companies were contacted and asked to design and estimate the cost of a rain garden, and one is recommended by the team. Since the BEER NUTS® facility is very close to the Constitution Trail in town, students proposed placing an educational sign at the section of the Constitution Trail close to the facility. The sign (Figure 4) will educate the public about the environmental benefit of a rain garden and the importance of storm water management.

Beneficial use of dredged materials

A student team worked with U.S. Army Corps of Engineers (USACE) on this project. As a result of USACE's continuous clearing of waterways for improved aquatic navigation, a surplus of more than 2,000,000 cubic yards of dredged material requires sustainable repurposing. After analyzing reports provided by USACE and related literature search, the student team proposed that engineered soil be created by mixing the dredged material with various amounts of agricultural by-product, municipal tree waste, manure, and backwater sediment, depending on the final beneficial use of the engineered soil. The team also identified five potential applications/markets where the engineered soil could replace current materials in construction, habitat building such as artificial and oyster reef creation/restoration, landfill covering and lining, soil remediation such as increasing moisture content, and soil for university farms (Schelinski et al, 2020; USEPA, 2024b). The student team conducted surveys across the five potential markets. Survey questions included feasibility considerations in terms of desired material composition, locations of the application sites, and costs associated with use and transportation of the dredged material. Finally, the team provided their marketability plan to USACE based on the results drawn from the survey results.

Feedback of participating students and clients

Since ICC is co-curricular, participating students do not complete a standard college course evaluation; instead, students are encouraged to share their reflections on the experience through a campus news platform. Student

TABLE 1. Themes from Students' Feedback

Themes	Example quotations that fit each theme
Civic engagement	"I chose this as a good way to get involved and make a positive impact on the community while learning as well." "I am more aware of community needs and felt that I could contribute and make a difference." "I am so excited to lead a project that gives back to and improves the community." "I was able to learn so much about my local community, our conservation efforts in play right now and what we could be working toward regarding conservation efforts in the future."
Real-world impact engages and excites students	"I think my favorite part of working on this has been knowing that the work myself and my teammates are doing is going to bring a real and tangible impact in the real world and someone's life. The knowledge that I played a part in helping someone has really made this all worthwhile." "Working with a real group has made everything feel much more substantial and impactful. I won't remember all the simulations I did in my classes, but I will remember the clients and the firms that we've worked with for this project." "Real-world clients equal real-world impact. The opportunity to help an organization attempting to create a valuable product for people in need is rewarding. Working in the real world is different because there isn't a blueprint or rubric to pull from. We have been given an issue and are trying to figure it out as best we can." "In the classroom, our ideas don't often move beyond the hypothetical. It was exciting to work on this project because we had the opportunity to propose solutions that will become a reality in the coming months."
Professional skills development (taking initiative, problem solving, teamwork, communication, presentation)	"It opens up a lot of doors and you have to teach yourself a lot." "Our mentors were definitely there for help, but it was mostly our group that set up all of the meetings and held ourselves to the deadlines." "You learn a lot of skills that you can apply to your career; definitely problem-solving and conflict management were two of the biggest things." "The project taught me how to collaborate with people from different backgrounds, how to organize better, and how to effectively communicate with my teammates." "Knowing this is a new class implemented in ISU, I find it to be one of the best I've ever taken. It truly dives in depth into problems and challenges you will come across in your life and will have to solve." "The final presentation was the most rewarding part of this experience. I look forward to seeing the launch of the merchandise line. It's fulfilling to see a project through from start to finish."

reflections from this news platform as well as mentors' observations during project meetings and final presentations are summarized in Table 1, with three themes identified. Because they take action and serve the local community, students feel strongly connected to it . The real-world impact truly engages and excites students; students feel that it is rewarding to make a difference and help people in the wider community. Finally, students feel they have made significant progress towards professional skills development, particularly in the areas of taking initiative, collaborating in a teamwork environment, problem solving, and developing communication/presentation skills.

Clients are generally pleased with their experience. Clients' feedback was drawn from observations at regular project team meetings, comments during final oral presentation and communication following submission of the final project report. Feedback from clients is summarized in Table 2 with three themes identified. Clients not only appreciate the information and new ideas student teams provided, but also concepts that were easy to act on. A few have already been implemented. Clients are also impressed with the professionalism student teams have demonstrated including taking initiative, problem solving and critical thinking skills, and good teamwork, as well as communication and presentation skills.

TABLE 2. Themes from Students' Feedback

Themes	Example quotations that fit each theme
Real-world solutions implemented	"Not only did we get the information we requested, they also provided us with many additional alternatives that we did not consider and one we ended up choosing." "They approached the task methodologically by first understanding the challenge, doing in-depth research and providing viable real-world solutions that can be implemented by my organization." "The students not only provided our department with new and exciting ideas, but also delivered concepts that were easy to act on, two of which have already been implemented this season."
Professionalism (taking initiative, communication, presentation, critical thinking, teamwork, problem solving)	"Regardless of the distance, they managed meetings and kept ongoing communications with my team and myself." "We met biweekly with the students, who had great questions. We were able to give them some direction, but they were creative in finding solutions and taking initiative to research the topic." "They were problem solvers. They asked for some information but were able to dig into it to find meaning and relevance. They looked at the problem from many different perspectives and provided suggestions from those perspectives. They also did not just provide one solution because of the complexity of the topic they worked on throughout the semester." "The presentation itself was professional, and I was impressed with the delivery of their material." "I'd be interested in participating more with ICC and doing more of these projects and getting more of our business units involved to get that exposure to thinking differently and to thinking longer term."
Assistance in decision-making	" The LED project was extremely helpful in our decision making, The team gave us the facts to clearly direct decision-making." "Depending on the information delivered and the conclusions drawn, that could help us make or break certain decisions that we may be indifferent about."

Discussion and Going Forward

A campus-wide student-formed consulting community provides an excellent interdisciplinary co-curriculum service-learning opportunity to connect students from different disciplines across campus to work on real-world problems and challenges in the local community while developing competencies and skills transferable to the workplace. Students feel strongly connected to the local community because of the actions they have taken to serve it. The real-world impact truly engages and excites students; students feel that it is rewarding to make a difference and help people in the wider community. Students also gain in their professional skills development, particularly in the areas of taking initiative, collaborating in a teamwork environment, problem solving, and communication/presentation skills.

These findings are consistent with outcomes of co-curricular service-learning reported in the literature (Hamid et al., 2024; Cruz et al., 2024; Baker & Esa, 2017; Mann & Casebeer, 2016). Marzouk (2008) presents several such programs at Virginia Tech and highlights the gain in students' civic engagement and leadership. John et al. (2019) show statistically significant positive influence in students' commitment to democratic values. Professional skill development is another prominent learning outcome that is well documented (Saddiky, 2020; Keen & Hall, 2009). Improved career opportunities and job interview skills are also reported (Cruz et al., 2024; the Ohio State University, 2020).

Civic engagement is defined as "working to make a difference in the civic life of our communities and developing the combination of knowledge, skills, values, and motivation to make that difference" (Ehrlich, 2000). At our university, civic engagement involves developing the combination of knowledge, skills, values, and motivation to make a difference in the civic life of our communities and promoting the quality of life in a community through both political and non-political processes. We believe that student-formed consulting communities follow this definition of civic engagement, and we should celebrate them.

There are various challenges encountered and lessons learned in this program. Financial support of a dedicated ICC faculty coordinator who is responsible for running the program is a necessity. In our case, a small endowment allows for one course release time each semester for the coordinator and nine months of support for a graduate assistant each academic year. Continuation of such financial support is essential for the viability of the program. Financial support of co-curricular service learning is a challenge that is often encountered (Moore & Gayle, 2010).

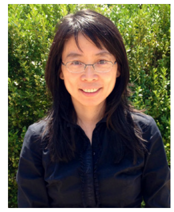
A substantial time commitment is another big challenge for co-curricular programs (Olewnik et al., 2023). In our case, we found that it is imperative to inform students early on of the time commitment so that they can plan their course loads or other responsibilities carefully for the following spring term when project workloads get intense. The issue of students dropping out of a project team a month or two into the semester has been addressed successfully after the time commitment has been explained and emphasized early on. However, for students who work 15 or more hours in addition to their classes, this program is not feasible. Providing this program with an alternative option as an independent study course could be a possible solution. Other ways to make this program more inclusive are resource intensive and will need university support.

The initial meeting between the student team and faculty mentors is also important. In that meeting, students can learn in more detail about the scope and the specific objectives of the project and what is expected of them, and then decide if this is the project for them.

Mentors are not compensated in this program. Faculty mentors view this not only as a great experiential learning and civic engagement opportunity, but also as an opportunity to collaborate with faculty from other disciplines and extend some of these projects to interdisciplinary research and grant opportunities.

Going forward, students will have the option of participating in this program for academic credit as an independent course. This will accommodate students who have to work significant number of hours on top of classes. We also plan to conduct a systemic assessment of this program including both quantitative and qualitative components. Feedback from the assessment will provide additional guidance on how the program could be improved. Since STEM majors are involved in this interdisciplinary program, feedback on the impact of this program on students' commitment to continuing in STEM careers will be included.

About the Authors



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Increasing Student Confidence in Data Literacy Through Experiential Learning

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Abstract
Scholars have noted a dearth of experiential learning components in STEM. This study seeks to address that issue by assessing learning outcomes for students who participated in a class with an experiential learning element and those who did not. For the experiential learning component, students, in collaboration with a community organization, designed survey instruments that measured college students' mental health concerns, analyzed the results, wrote papers and presented posters of the findings. Students in the experiential learning class (ELC) had statistically increased confidence levels in comprehending scientific ideas, creating graphs, and discussing results, while their peers did not. Students reported that the experiential learning component helped them understand topics in their STEM class better. Given that many students in the ELC aspire to pursue healthcare professions, the increased confidence in understanding data through hands-on experience should help prepare them for the interpretation of clinical data and thus potentially benefit their future patients.

Introduction
STEM classes have a unique opportunity to engage with communities and/or community partners through projects that center on data collection and analysis. These projects require data literacy. Data literacy is commonly defined as the ability to understand and interpret real-world datasets and communicate the findings to others (Gibson and Mourad, 2018; Kjelvik and Schultheis, 2019). The necessity for data literacy has become ubiquitous across professions (Kjelvik and Schultheis, 2019; Schreiter et al., 2024). However, this is not a skill that is generally taught in K–12, and many college students struggle with

the basics of making and interpreting graphs (Schreiter et al., 2024; Harsh and Schmitt-Harsh, 2016; Gibson and Mourad, 2018). Real-world problem sets can improve data literacy by enabling students to connect the lecture material with the appropriate dataset and analysis tools and can allow students to experience the process of analysis organically (Hicks and Irizarry, 2018; Langen et al., 2014; Kjelvik and Schultheis, 2019). The use of authentic data has also been shown to motivate students to understand and find answers to research questions, see how data literacy will be valuable in their future professions, and improve student learning outcomes (Langen et al., 2014; Harsh and Schmitt-Harsh, 2016). Experiential learning in STEM is one way that students can use authentic datasets to become data literate. Unfortunately, experiential learning is still relatively less common in STEM than in other academic fields. In a recent review of STEM projects, only a quarter had any form of experiential learning. Even then, when experiential learning was included, it tended to focus on specialized techniques rather than on general knowledge (Remington et al., 2023).

The first and third authors of this paper designed and taught the experiential learning class (ELC) that focused on teaching data literacy, an essential general knowledge skill in STEM. Students created a survey about the mental health needs and concerns of college students, distributed the survey and analyzed their results. The ELC collaborated with a community partner who shared their interest and expertise in assessing and improving college-age students' mental health. The ELC culminated in written reports and graphic posters that were presented to the partner and the campus community. To test the efficacy of the ELC, we used data from professor-led surveys that were collected at the beginning and end of the semester to assess students' perceptions of their data literacy skills. The data revealed that by the end of the semester, students in the ELC had statistically higher confidence in their scientific ability, while their peers in the control group did not. This study shows that using authentic data in experiential learning can improve students' confidence in key aspects of data literacy such as creating, reading, presenting, and graphing data. As we move into an increasingly data-driven medical system, experiential learning classes that work with data can help prepare aspiring healthcare professionals.

Methods

Institutional Setting and Class Format

The institution is a liberal arts college located in the United States. It is a primarily undergraduate institution, with approximately 1800 undergraduate and 500 graduate students. The college requires freshmen to participate in a first-year program (FYP) where they take two content courses taught by two different professors, and a third class co-taught by both of the professors. The third class is an interdisciplinary class where both professors incorporate their disciplines to create a writing- and reading-intensive course. In this course, as a requirement of the college, professors must assign primary literature in their fields as well as a research paper in their fields or with an interdisciplinary connection between their fields.

Student-Led Survey Topic

The professors of the ELC and community partner selected the topic of mental health for the student-led survey. The community partner runs an organization dedicated to understanding and improving the mental health of children and young adults in the area. Courses with community engagement generally focus on a problem that is in urgent need of attention (Rimm-Kaufman et al., 2021). According to a meta-analysis with over 20,000 student respondents, mental health among college students is an increasing concern, as rates of anxiety and mood disorders have risen in recent years (Buizza et al., 2022). The professors of the course selected mental health because of student interest in the topic. Students in previous iterations of the ELC had expressed the highest interest in mental health when choosing between that and topics of drug usage, alcohol usage, and anti-racism. These students ranked these 4 topics from their most desired survey topic to their least desired topic. All of the students ranked mental health as their most desired topic, except for one student, who ranked it as their second most desired topic.

Participants

Fourteen students in the ELC and 24 students who were not in the ELC (referred to in the text as the control group) completed both the pre- and post-surveys. The college requires that all first-year learning communities include formal research papers, as well as intensive

TABLE 1. Comparison of Course Content

Interdisciplinary Course	ELC	Control Class 1	Control Class 2
Intensive writing and reading	Required	Required	Required
One or more presentations	Required	Required	Required
Community engagement component	Semester-long (20+ hours)	None	None
Volunteering (not related to class content)	None	None	Four hours
Class size	*14	28	21
Response rate for professor-led survey	100%	43%	57%
Concurrent STEM course topic	Microbiology	Microbiology	Experimental psychology
Concurrent non-STEM course topic	Art	Literature	Philosophy

*Note: The class size in the ELC was capped at 14, a limit imposed by the arts course.

reading and writing. Both classes used as the control group were selected based on the inclusion of STEM content in the interdisciplinary course, so that all courses would contain intensive scientific reading and writing, making our data-driven experiential learning curriculum the distinguishing feature (Table 1; Figures 1, 2). In one interdisciplinary control group, students took an introductory microbiology course and an introductory course in literature. In the other control class, students took an introductory course in experimental psychology and an introductory course in philosophy. In the ELC students took a microbiology course and an art course. Thus all 38 students participated in a STEM content course, as well as in an interdisciplinary course that contained intensive reading and writing in STEM. However, only our course contained a semester-long experiential learning project. A comparison of the courses is provided for clarity (Table 1). STEM is defined in accordance with the National Science Foundation and the Department of Homeland Security and Immigration and Customs Enforcement and includes courses in the physical sciences as well as psychology (Li et al., 2020; Gonzalez and Kuenzi, 2012).

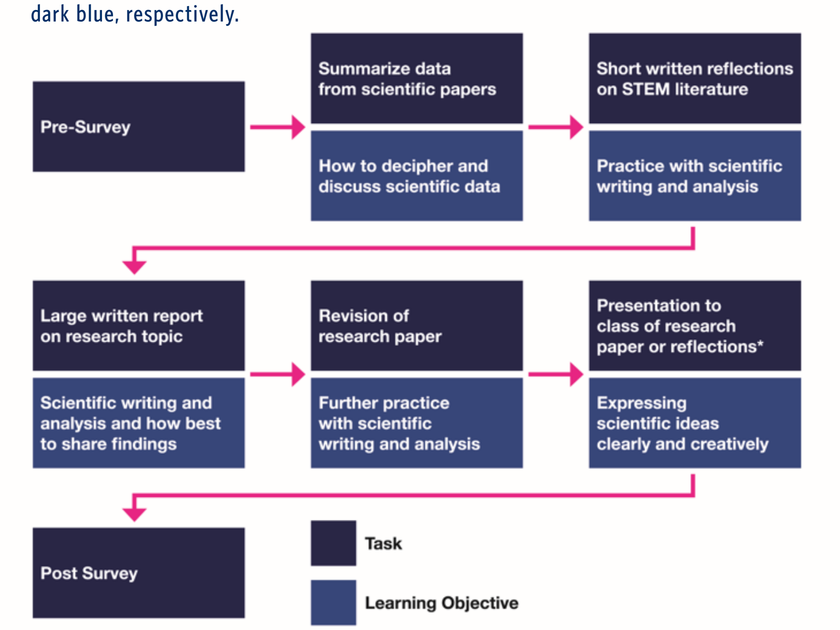
Experiential Learning Class

The two professors created an interdisciplinary course where students designed surveys regarding mental health among college students, distributed the surveys on campus, and analyzed the results graphically (Figure 1). Their required research report analyzed their student-led surveys, producing graphs and reflecting on the results, with particular emphasis on contextualizing the results and what they mean for the community partner. Students then made posters based on their survey findings, further forming their data analysis into concrete ideas. Throughout the class, the professors encouraged careful analysis of the results, highlighting the ways in which data is misconstrued.

Much like the control groups, the ELC started the semester with reading scientific literature and writing short assignments about it (Figures 1, 2; Table 1). The ELC also

FIGURE 1. Timeline of the course for the ELC during the semester. Main learning objectives in data literacy and the tasks that the students were assigned are shown in light and dark blue, respectively.

FIGURE 2. Timeline of the course for the control classes during the semester. Main learning objectives and the tasks that the students were assigned are shown in light and dark blue, respectively.



* Indicates that in one of the control classes the students presented their research papers and in the other control class students presented their reflections.

read multiple papers. Particular emphasis was placed on papers that had useful messages for data literacy. For example, the first paper we read as a class was a paper that was retracted (Wakefield et al., 1998). Students summarized that paper for homework, then engaged in group activities to identify flaws in the paper that caused it to be retracted. In this way, students were introduced to essential concepts of data analysis such as sample size. Each group examined specific figures, requiring students to focus on graphical interpretation. Other papers, such as Westphal et al. (2015), focused on analyzing survey results with student-accessible statistical tests such as ANOVAs and t-tests. Students were taught what a t-test is and how to interpret the p-value they received. Students were encouraged to utilize these when doing their surveys. Students were also taught how to calculate error rate based on their sample size. Interpretation of their error rate was a required component of their final report. The community partners also advised the students on how to design clear surveys and identify common flaws in survey design, such as double-barreled or leading questions. After the community partners finished their presentation, students were given time to look over their own surveys and apply their newfound knowledge to improve their survey questions.

When the time came for students to analyze their own survey results and generate figures, multiple classes were dedicated to students working in their survey groups. During the first class period students worked with data provided by the professors, to get used to graphing and analyzing data in Microsoft Excel. In multiple subsequent class sessions, students worked in their survey groups to analyze and identify patterns in their own student-led survey data. Students were required to graph the same data multiple ways in order to highlight how different graphs can reveal new interpretations of the same data. Problems with individual datasets came up organically, and the professors of the course would use these as teaching moments for the class. For example, one group struggled to interpret their survey results at first, but a discussion of how they administered the survey helped the group realize that they had biased their results by asking significantly more women to take the survey than men. A deeper discussion of how to identify bias in a survey followed and caused other groups to identify bias in their own survey results. When students wrote their final report, they were required to contextualize their results using primary and secondary research articles. Above all, students were encouraged to question the results in front of them, and to cultivate careful data analysis and interpretation.

Community Partner Benefits

Both the community partner and the participants should benefit from a shared project (Hayford et al., 2014). The class was structured so that the work the students did would be relevant and meaningful for the community partner. The students' research report was designed to give the community partner an accessible way to understand and utilize the results generated by the students and all data was presented to the community partner at the end of the semester. All material generated by the students was shared with the community partner in an organized fashion.

Informed Consent and Mixed Methods Analysis

This research was approved by the College's Human Experimental Review Board. The Likert response options of strongly disagree, disagree, neutral, agree, and strongly agree were converted to 1-5 respectively. Once converted, paired t-tests were used to compare the pre-and post-surveys (Sullivan and Artino, 2013). As multiple t-tests were performed, type one error was controlled using Benjamini-Hochberg (Benjamini and Hochberg, 1995).

Students in the ELC were asked to elaborate on their answers to the Likert scale questions in short response. If they answer mostly confident, they were asked to describe why they felt confident, if they answer mostly not confident, they were asked to describe why they felt not confident. Their responses to these questions can be seen in Table 3. To analyze the short responses, we first grouped the short responses by what each student responded on the likert scale questions in the pre-survey. If students responded to ≥ 5 of the 8 likert scale questions by selecting strongly agree or agree in the pre-survey, then their short responses were considered confident overall. If students responded to ≥ 5 of the 8 likert scale questions by selecting neutral, disagree or strongly disagree then their short responses were considered not confident. Further, each student's individual responses from the pre-survey were compared to the post-survey to investigate how individual students' responses changed throughout the semester (Table 3).

Results of the Professor-Led Survey

Improvement in Confidence in Reading Comprehension (Question A)

Question A examined students' overall confidence reading scientific papers and comprehending the main ideas (Figure 3A, Figure 4A, Table 2). The ELC increased significantly and the effect size was 0.79 (Figure 3A, p-value <0.01). Surprisingly, the students' confidence in reading scientific literature in the control group decreased during the semester, though the decrease was not statistically significant (Figure 3A). This was unexpected as students in the control group are required to read within their disciplines, and exposure to scientific material should increase confidence (Table 1, Grzyb et al., 2018). Further, this question did not relate to any specific requirement within the ELC, as all classes were required to have intensive reading within their disciplines. This finding suggests that experiential learning improved confidence in scientific literacy skills in general, not just those related directly to the student-led survey itself.

Continued Confidence in Graphing Comprehension (Question B)

Students in the ELC displayed continued confidence in interpreting graphs during the semester (Figure 3B, Figure 4B). Students did not increase in confidence because of the high number of students who selected strongly agree on the pre-survey (57 percent). All other questions

TABLE 2. Likert Survey questions for all classes for both the pre-and the post-survey. A-H questions correspond to A-H in Figures 3 and 4.

QUESTION
A. I feel confident in my ability to comprehend the main ideas in scientific papers.
B. I feel confident in my ability to comprehend what a pie or bar graph is showing in a scientific paper.
C. I feel confident in my ability to clearly share and discuss scientific results from survey data with scientists and/or professors.
D. I feel confident in my ability to clearly share and discuss scientific results from survey data with a layperson (a person without any specialized or professional knowledge).
E. I feel confident in my ability to create a graph from survey data that can be easily understood by a scientist/professor.
F. I feel confident in my ability to create a graph from survey data that can be easily understood by a layperson (a person without any specialized or professional knowledge).
G. I feel confident in my ability to design a scientific poster/graphic based on survey data that can be easily understood by a scientist/professor.
H. I feel confident in my ability to design a scientific poster/graphic based on survey data that can be easily understood by a layperson (a person without any specialized or professional knowledge).

ranged from 7 percent to 36 percent of participants selecting strongly agree on the pre-survey. Students in the control group decreased their confidence in interpreting these graphs but the decrease was not statistically significant (Figure 4B).

Improvement in Confidence When Discussing Scientific Results (Questions C and D)

Students in the ELC increased their confidence in their ability to share and discuss scientific results with both scientists/professors and laypeople (Figure 3C and D, p-value<0.05 for both). ELC students were required to present their posters twice, once to their peers and once to the community partner at the end of the course. They also wrote research reports on their survey results. Students' confidence in the control group did not increase significantly for either question (Figure 4C, D). This non-significant finding was not due to a lack of presentations. Students in the control group were required to have between one and three presentations (Table 1). However, their required presentations did not include their own generated data of any kind. These results suggest that using authentic data can increase confidence in presenting scientific material. However it should be noted that because the ELC presented twice, and some of the control group only presented once, that the difference we see could be due to the higher number of presentations within the ELC.

Improvement in Confidence When Creating a Graph (Questions E and F)

Students in the ELC significantly increased their confidence in creating graphs that can be understood by a professor/scientist but not by a layperson (Figure 3E, p-value<0.01, Figure 3F, p-value>0.05). Question E asked about creating a graph based on survey data for a scientist/professor. The effect size for this was large, 0.86, highlighting the significant increase from the pre-to post-survey. Question F asks about creating a graph that can be easily understood by a layperson. It is possible there is no significant difference between the pre- and post-survey because of the number of students who were already highly confident during the pre-survey (36 percent for strongly agree, 50 percent for agree) offering little opportunity for improvement. The control group decreased in their confidence in creating graphs for scientists, professors, and lay people, as the average change in response decreased for both questions, but the decrease was not statistically significant (Figure 4E, F).

Improvement in Confidence When Designing Scientific Posters (Questions G and H)

Students in the ELC increased significantly in their confidence in their ability to design a scientific poster or graphic for scientists, professors, and laypeople, with all students selecting neutral, agree, or strongly agree for

FIGURE 3. Results of the pre-and post-survey for the professor-led survey for the ELC using paired t-tests. All questions were ranked on the Likert scale from strongly disagree, disagree, neutral, agree and strongly agree from 1 to 5, respectively. Effect size rounded to the nearest hundredth for A-H respectively (d= 0.79, 0.45, 0.6, 0.8, 0.86, 0.42, 1.09, 1.24). Average change in response (post-survey subtracted by pre-survey) is rounded to the nearest tenth for A-H respectively (0.6, 0.4, 0.4, 0.6, 0.6, 0.3, 0.9, 1). *, **, and *** represent p-values less than 0.05, 0.01 and 0.001, respectively.

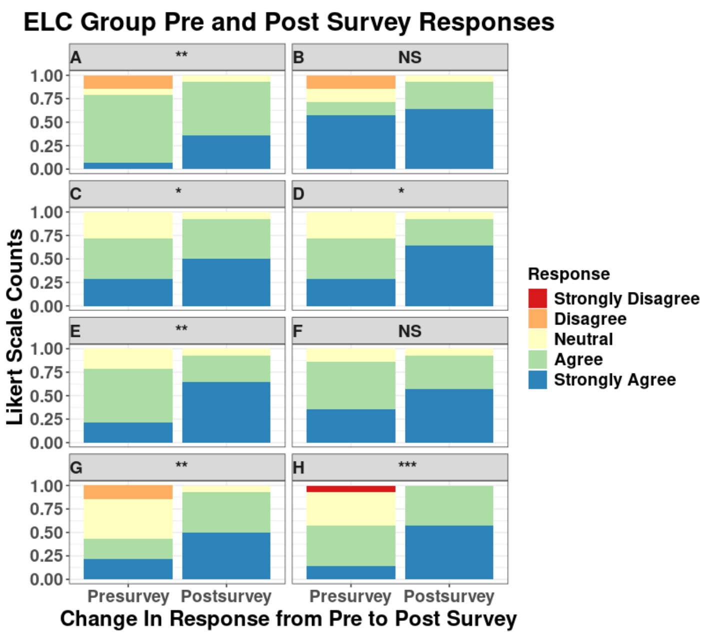
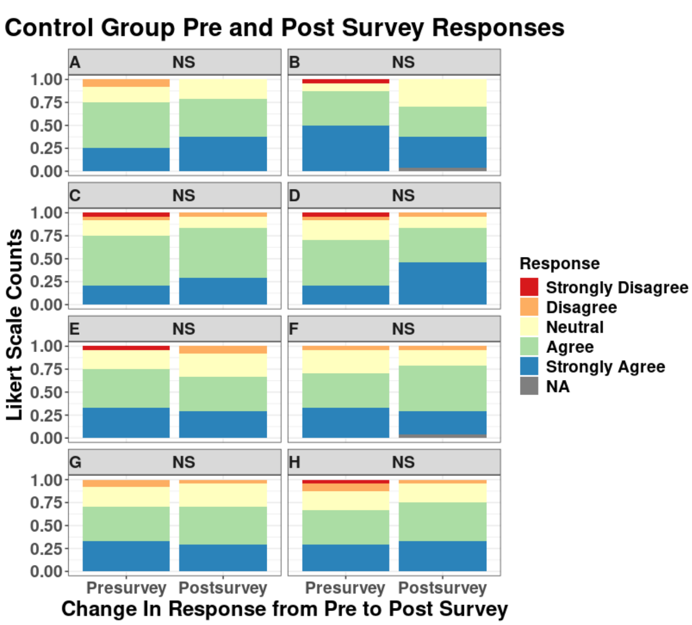


FIGURE 4. Results of pre-and post-survey responses for the professor-led survey for the control group using paired t-tests. All questions were ranked on the Likert scale from strongly disagree, disagree, neutral, agree and strongly agree from 1 to 5, respectively. Effect size rounded to the nearest hundredth for A-H respectively (d= 0.14, 0.15, 0.21, 0.14, 0.03, 0.10, 0.11, 0.25). Average change in response (post-survey subtracted by pre-survey) is rounded to the nearest tenth for A-H respectively (0.2, -0.4, 0.3, 0.5, -0.1, -0.2, 0, 0.3).



both questions in the post-survey (Figure 3G, p-value<0.01, Figure 3H, p-value<0.001). The students demonstrated the highest increase in confidence in their ability to make scientific posters and graphics. This might be because the scientific poster was the final assignment. As their confidence built during the semester in data literacy, the final task would potentially cause the biggest increase from pre-to post-survey. The control group did not increase significantly (Figure 4G, H).

Short Answer Responses

In addition to questions that asked students to rate their confidence level about scientific literature comprehension on a Likert scale (Figure 4), the professor-led survey featured open-ended questions that asked participants to elaborate on why they do or do not feel confident in their abilities surrounding data literacy (Table 3). Only students in the ELC completed this part of the survey. In the pre-survey 69% of all students surveyed felt confident (responding somewhat agree or strongly agree) about their abilities, while others felt less confident (responding with neutral, somewhat disagree, or strongly disagree) about being able to analyze and interpret data. In the post-survey, we found that some of the less confident respondents felt better equipped to discuss and analyze data. For instance, a student in the ELC who initially responded that they did not "have a lot of experience in graphing and understanding scientific papers" found that by the end of the semester they felt that they had been "well-prepared by my LC professors to visually and vocally conduct/display information from a survey."

Another student in the ELC, who responded to most of the questions by saying that they somewhat agreed that felt confident expressed that they felt "mostly neutral for most of these because I have not dealt with graphs enough to be confident about them." In the post-survey, this student responded to

TABLE 3. Likert Survey questions for all classes for both the pre-and the post-survey. A-H questions correspond to A-H in Figures 3 and 4.

PRE-SURVEY RESPONSE	POST-SURVEY RESPONSE
" Unlike some others, I feel very confident in conversations with people, whether it be family or complete strangers. I have always felt it essential to learn to communicate no matter what their	" I have been well-prepared by my LC professors to visually and vocally conducted/ display information from a survey."
"I feel confident that I am going to be able to design a scientific poster because my teachers seem like they can explain the programs well and clear. It also seems very hands on in this class	"I am confident after taking these classed i got the skills needed to complete the above taks."
No response recorded	"The LC taught me to do these"
"From my prior education i am somewhat confident that I would be able to do these things"	"i feel confident because we have went over a couple of scientific papers this semester"
"I am not good with art and posterd"	"Because I have been working with them this semester"
"I somewhat agree because I've seen examples of how data is collected and feel as if I have an idea of how to collect scientific data and present it"	"I feel we were informed in class on how to complete the tasks above"
"I don't feel confident because I don't have a lot of experience in graphing and understanding scientific papers."	"I feel neutral for most of them because I feel like I don't completely understand how to comprehend a graph, or make one."
No response recorded	"I feel confident because in this class we have made surveys, graphs and interpreted them multiple times."
"I did agreed for the majority because I know the general knowledge and basics of comprehending scientific research, but not to the point where I would be strongly confident enough discuss with someone who is more experienced in the area."	"I feel confident because I learned about it in highschool and we went over it in class."
"I feel confident because I have done most of these tasks before in another class in high school."	"I have learned how to and have done it before"
"I feel somewhat confident because I have done this before"	"Because my professors in my LC really taught us how to read scientific articles and make posters, surveys, and graphs."
"Simply because we were never taught how to do these things in highschool"	"I feel confident for the simple fact that it has been something we have been doing for the past few months"
"I feel mostly neutral for most of these because I have not dealt with graphs enough to be confident about them."	"My professors greatly explained to us how to read and write numerous kinds of scientific material. Whether it was charts or papers, they taught us exactly what is expected from them. This had made me confident enough to know i would be able to explain any scientific data to someone with or without the knowledge i have"

the same question: "my professors greatly explained to us how to read and write numerous kinds of scientific material. Whether it was charts or papers, they taught us exactly what is expected from them. This had made me confident enough to know I would be able to explain any scientific data to someone with or without the knowledge I have."

Even a student who had previous experience with data interpretation remarked on the post-survey, "I am confident after taking these classes I got the skills needed to complete the above tasks." While all students responding to the short answer in the ELC wrote about increasing confidence, not all increases were as substantial. One participant stated in the pre-survey that they didn't "feel confident because I don't have a lot of experience in graphing and understanding scientific papers." In the post-survey, they felt "neutral for most of them because I feel like I don't completely understand how to comprehend a graph, or make one." Overall, students' short responses concurred with those of the Likert questions, demonstrating that students felt increased confidence in performing tasks involving data analysis.

Student Assessments

In the ELC students submitted a written report and poster detailing their main findings. While there were no questions on the survey that tested their knowledge of the scientific material, we did observe improvement throughout the semester in students' ability to accurately graph and describe data. At the beginning of the semester, students were able to summarize scientific texts effectively, but were not able to go beyond that and question the results, identify flaws, or provide suggestions for future directions. Further, students struggled with the basics of graphing such as navigating Microsoft Excel and identifying the independent variable in their datasets. However, as students practiced examining their data and writing about their results, the professors of the course observed a change, particularly in the way that students were able to dissect their data. By the final report, the majority of students were able to identify flaws within their survey design, propose effective solutions for future surveys, and discuss scholarly literature that related to their results. Students were also able to successfully apply what they learned from their surveys to suggest possible solutions and ideas for the community partners.

Discussion

While experiential learning is more commonly found in social sciences and humanities, there are a growing number of STEM faculty who teach classes that have a community engagement component (Remington et al., 2023; Collins et al., 2020; Walser-Kuntz and Iroz, 2017; Daniel and Mirsha, 2017; Hayford et al., 2014). Our results suggest that when experiential learning is integrated into STEM classes, students' confidence in their ability to comprehend, discuss, and create data increases (Figure 3). In contrast, there were no significant increases in confidence for the control group for any of the eight questions (Figure 4). Both the control and the ELC were required to read and utilize scientific literature in their classes, but only the ELC increased significantly in their confidence in reading scientific papers (Figure 3A).

While not statistically significant, the survey results show that the control group did decrease in confidence in multiple categories, including reading scientific literature, interpreting graphs, and creating graphs (Figure 4). Reading scientifically was particularly surprising, because both control classes had research papers where students had to utilize scientific scholarly literature. This indicates that the practice that they received did not equate to increased confidence. One reason for this could be that they were required to read scientific scholarly articles and write scientifically without having any hands-on experience with graphing and analysis and thus had no benchmark to compare their research to. Experiential learning in the ELC gave students a concrete example that they could use to connect to the scientific articles they read. Experiential learning has also been shown to have higher engagement with scientific material (Langen et al., 2014). Perhaps students in the control class decreased in confidence because they felt more disengaged from the material, causing them to perceive that they understood less.

In the short responses, ELC students discussed having more scientific understanding and confidence by the end of the semester. Their responses were expansive, with some students noting that they felt they could now describe any type of scientific data to other people. This result further suggests that the increase in confidence goes beyond the survey data analysis performed in class. When combined, the short response and the professor-led survey results indicate that it is possible for experiential learning to increase confidence in scientific skills in general, beyond those directly associated with the experiential component of the course.

Data interpretation was identified as one of three essential skills STEM students should gain during college (Coil et al., 2010), and students report more interest in community engagement when projects provided career related skills (Caspersz and Olaru, 2015, p. 691; Coker et al., 2017). When combined with the fact that data literacy is a skill many students struggle with, programs that can combine data literacy and experiential learning can prepare students for their future professions (Harsh and Schmitt-Harsh, 2016; Gibson and Mourad, 2018). Our study provides evidence that when using experiential learning students' confidence in their ability to interpret data can increase significantly. Current research suggests that teaching data literacy analysis through the example of real-world datasets improves students' ability to understand these critical skills (Hicks and Irizarry, 2018; Langen et al., 2014; Kjelvik and Schultheis, 2019). This paper provides further support for this conclusion, as students in the ELC gained significantly more confidence. While studies with experiential learning that measured students' confidence in regard to designing their own research questions and protocols have had mixed results (Gormally et al., 2009; Rissing and Cogan, 2009), our ELC uniquely focused on a topic that students had reported interest in, and students worked closely with community partners using authentic data. Neither of the previous studies mentioned student interest in the experiential learning topic chosen (Gormally et al., 2009; Rissing and Cogan, 2009). It is possible that our students showed an increase because our student-led topic was selected based on student interest, and thus students were more motivated to excel, resulting in more confidence in their skills by the end of the semester. Our study suggests experiential learning can improve students' confidence in science in reading, creating, presenting, and interpreting data. We hypothesize that the ELC's practice of working directly with authentic data contributed to the students' increase in confidence in data literacy.

While we have demonstrated that students' confidence improved, we note that our study has limitations. We did not include survey questions that would test their knowledge of scientific material, and so we cannot conclusively say that our students have higher levels of knowledge in data literacy from pre- to post-survey. However, positive relationships between self-confidence and academic performance have been reported previously, suggesting that students who have more confidence in themselves may also excel academically at higher rates (Abdulghani et al., 2020). Further, the professors of the course observed an improvement in the way that students approached scientific data, from being able to summarize it at the beginning of the semester, to being able to question and critically analyze it by the end of the semester.

We note that many of our questions are specific to the type of data that students encountered in the ELC. We wanted our questions to focus on what the ELC was doing so that we could directly quantify whether they improved. There exist many ways of graphing and discussing results beyond survey data, and thus some of our questions are limited in their scope. However, both the short response and Figure 3A demonstrate that students in the ELC expanded their confidence beyond just survey data. Our study is done on a small sample size (Table 1). A larger future study could investigate whether students in an experiential model gain confidence across a broad range of scientific skills. Using a survey model, where the project changes but students still design, implement, and analyze a survey to learn the core components of data literacy, would test whether the results seen here could be generalized across disciplines. Despite its limitations, this study demonstrates the importance of experiential learning in STEM forboosting student confidence in a variety of essential scientific skills.

This study presents a successful format for educators who desire to teach data literacy. There are currently few examples of how to teach data literacy in the classroom and even fewer rigorous scientific articles that investigate the efficacy of teaching science literacy through community engagement (Hayford et al., 2014). Our paper employs multiple mechanisms to provide rigor to our experimental design. Using both pre- and post-surveys, as well as a control group, our paper contributes to the need for more rigorous studies. Further, few STEM projects contain experiential learning with general skills like data literacy (Remington et al., 2023). Since this survey model can be used with any topic, teaching data literacy through a student-led survey can be a useful tool for professors interested in fostering community engagement and increasing data literacy across a variety of disciplines and student populations.

Conflicts of Interest

The authors of this study declare no conflicts of interest.

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