Board 42: "Integrating Undergraduate Research Across Disciplines: Supporting an Externally Collaborative Project-Based Interdisciplinary Culture (EPIC) for Learning using Trace Metal Analysis"

Dr. John W. Duggan, Wentworth Institute of Technology

Jack Duggan is Professor and Chair of Civil Engineering at Wentworth Institute of Technology at Wentworth Institute of Technology. He is a registered professional environmental engineer in the Commonwealth of Massachusetts. He has earned a B.S. in Chemical Engineering from Clarkson University and M.S. in Civil Engineering and Ph.D. in Chemistry degrees from UMASS Lowell.

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Background

A project to demonstrate that undergraduate research is effective in accomplishing the newly adopted learning style at Wentworth Institute of Technology called EPIC Learning (i.e., Externally Collaborative Project-Based Culture for Learning) was conducted using a variety of undergraduate research projects that focused on trace metals analysis. EPIC Learning was adopted for all degree programs at Wentworth in 2014. The objectives of EPIC Learning include the promotion of interdisciplinary collaboration between degree programs and establishment of a project-based culture of learning for all Wentworth students in order to better prepare graduates for multidisciplinary projects they will encounter in the workplace.

At Wentworth, EPIC Learning often incorporates service projects with external collaborators from outside of the immediate Wentworth community. Such groups include community groups, K-12 schools, private corporations and professional associations. This project was designed to allow undergraduate students to work with external collaborators while conducting meaningful undergraduate trace metals research using atomic absorption spectrometry. As an institution that has only recently achieved university status, this project hoped to help create a culture of research on campus.

Summary

This paper describes a program initiated to promote interdisciplinary undergraduate research at Wentworth through a shared interest across many areas of study, i.e., the measurement of trace metals in environmental and other matrices. The identification, measurement and control of trace metals in environmental and other media (including soil, water, electronics, pharmaceuticals, ceramics, food, art supplies, etc.) was chosen as a focus of this project because the subject is interdisciplinary by nature and projects of concern were expected to promote collaboration across different disciplines for both students and faculty.

Throughout the project, students and faculty from multiple disciplines learned principles and methods of metals analysis and worked together on a wide range of trace metal research projects. The project was supported by the National Science Foundation Major Research Instrumentation grant program. This paper both summarizes the projects conducted and describes the challenges and opportunities experienced over the course of the project with the intent of exchanging ideas and establishing successful approaches to collaborative interdisciplinary undergraduate research.

In the process of conducting trace metals research, project outcomes were accomplished.

1. The project provided opportunities for faculty development and faculty development occurred;
2. The project integrated STEM and non-STEM elements into each research topic and provided outreach to K-12 students in the local community;

3. The project provided research and service opportunities to undergraduate students, allowed them to work in interdisciplinary teams and better prepared them for success in their professional degree careers;
4. The project provided a model for future undergraduate research-based EPIC Learning opportunities at Wentworth.

The project was designed as a set of different undergraduate research projects that include the common theme of metals analysis. Multiple research projects were conducted by a team of interdisciplinary faculty (the PI and co-PIs as well as other faculty and staff) with students from differing majors. The students and faculty share the atomic absorption instrumentation, receive training together and collaborate on the individual projects. Such a collaboration has been unique at Wentworth. The project was also designed to establish a permanent culture for such interdisciplinary collaboration for future undergraduate research opportunities. The individual projects differed in organization and structure. Some projects were embedded in courses while others were performed as extra-curricular projects. The differences in organization and structure helped identify aspects of a more sustainable model for expanding undergraduate research projects in the future at the Institute.

Major Activities Conducted to Meet Goals and Measure Outcomes

Major activities for the project designed to meet project goals included: development of project-specific analytical methods; faculty, student and staff training on sample preparation and instrument operation; and undergraduate research and student presentation of results. These activities were conducted to measure specific project outcomes.

Major Activities

1) Development of Project-specific Analytical Methods

As the individual undergraduate research projects evolved, analytical methods using the instrumentation continued to be modified to improve detection limits, accuracy and precision. The instrumentation allowed the research teams to use both flame and furnace components and this has provided the opportunity to tailor analytical methods that best fit the metal(s) of interest in the sample matrix. Method development has also provided participating students the ability to learn the importance and relevance of optimizing analytical methodologies in order to confidently measure trace metals in a sample. Each project required unique sample preparation methods. For example, sample preparation in the "Buried Treasure" project (a collaborative project that involved engineering, art and history disciplines) included development of a digestion method as well as a non-destructive method to preserve archeological glass and ceramic artifacts.

2) Training

Instrumentation training was an ongoing program throughout this project. While the Principal Investigators received initial training once the instrument was installed and operational, students regularly received training each semester as they joined an ongoing

or new research project. In addition, other individuals, including lab technicians supporting the project also received training on the operation of the instrument. The frequency of training new individuals has resulted in standard procedures for introducing students and others to the theory of atomic absorption, methods of sample preparation, flame and furnace operation and data acquisition. Written operating procedures for flame atomic absorption and graphite furnace atomic absorption have been created to support faculty, staff and student training.

3) Undergraduate Research and Student Presentation of Results

Over the period of September 2016 to August 2018, fourteen undergraduate research projects were performed. Project results have been presented to a wide range of audiences, including K-12, undergraduate students, graduate students and practicing professionals. Project participants included 39 undergraduate students, 11 faculty (including the PI, co-PIs, other Wentworth faculty and one external collaborator from another college) and 2 laboratory technicians, representing seven different academic programs/disciplines from the Colleges of Engineering and Arts and Sciences. In addition to mentoring students during their research, a considerable effort was given to supporting students in their presentation of their results at venues that included regional, national and international conferences. Presentations were also made in a K-12 classroom and elsewhere to K-12 audiences.

Specific Objectives

Faculty Engagement and Development

The first year of the project was intended to support faculty in developing sampling methods, sample preparation methods, analytical protocols, and development of assessment methods. These tasks were accomplished and continued to be refined and optimized for the research projects conducted throughout the life of each project. Continuing refinements include instrumentation-specific details such as standard operating procedures and project-specific objectives such as modifying analytical methods to improve detection limits, optimizing sample preparation methods and improving workflow in and around the new instrumentation. A principal objective in the second year of the project was to establish ongoing undergraduate research projects, obtain preliminary results and perform initial data interpretation. This was accomplished for multiple projects in years one through three and continues for several projects that remain ongoing.

Impact on Faculty Development and Collaboration and Undergraduate Research

The fifteen projects took several forms, adapting to the existing academic framework of the Institute. Some projects were embedded in undergraduate project-based coursework, some were part of “Capstone” projects and some were entirely extra-curricular student projects. The framework of the project affected the level of engagement of the participating faculty. Despite the form of the project, it was clear that all research efforts

conducted as part of the project required significant staff support (i.e., laboratory technicians) to both mentor students and maintain analytical instrumentation.

To date, all but two projects produced a peer-reviewed work product (such as a final report, paper or poster presented at a professional conference or exhibited work) that has helped disseminate project accomplishments to a wide range of audiences. The project titles are summarized in the following Table, including the number of undergraduate students and faculty and staff involved in each project.

Title	**Period of Activity**	**Students Participating**	**Faculty & Staff Mentors**	**Work Product**
Lead Concentrations in an Urban Soil	9/17-10/18	7	2	Poster
Evaluating the Heavy Metals Adsorption Capacity of Hemp	5/17-10/18	3	2	Paper & Poster
Using Plastic Bags in Roadways	5/18-present	2	1	Poster
Buried Treasure (Metal Analysis of Glass)	7/18-present	0	8	Exhibit & Paper Abstract
A Test of Low-Cost Particulate Matter Sensors for Industrial Air Quality Hazards	9/17-present	0	3	Paper
The Design of a Water Purification Device: Metals Reduction	9/17-5/18	4	4	Poster & Final Report
Lead in Water Bubbler Samples from Campus Buildings	5/16-10/17	4	3	Poster
Northern Avenue Bridge Sediment Analysis for Lead	5/16-10/17	4	3	Poster
Evaluating the Efficiency of Low-Cost Ultrafiltration	5/16-10/17	4	2	Poster
Adsorption of Chromium from Water using Innovative Low-Cost Organic Materials	5/16-10/17	6	3	Poster
Metals Analysis of Biodiesel	5/16-unknown	2	2	None reported

Toxic Synergistic Effects of Magnesium in Different Allergy Medication	9/16-5/17	1	3	Poster & Final Report
Measurement of Lead and the Characterization of Other Anthropogenic Materials in Surficial Urban Soil	9/16-10/17	1	2	Poster
Treatment of Waste, Oily Sludge and Slurries	5/16-5/17	3	4	None Reported

Impact on Promoting Campus External Collaborations

Over fifteen external collaborators, the majority of which have not collaborated in undergraduate research in the past, have participated in the individual projects. These collaborators have provided insight to the technical details of the projects and/or provided mentorship to participating student researchers. The project has helped faculty development in terms of promoting ways faculty can identify and partner with external partners in order to create future undergraduate research opportunities.

STEM outreach

Over the three years of the project, outreach has been made to external collaborators for K-12 and community groups to share science aspects of the projects. Demonstrations of the atomic absorption instrument have been used in summer STEM programming to City of Boston public high school students and to City of Boston elementary school students. In several instances, undergraduate students working on projects presented their research to students to K-12 students.

Conclusions

The project demonstrates how undergraduate research can be conducted by students within the EPIC Learning curriculum framework recently established at Wentworth. One project goal was to promote undergraduate research within the evolving culture of EPIC Learning on the Wentworth campus for all majors. It is expected that the project will impact all disciplines on campus by being a model for integrating multi-disciplinary undergraduate research in the curriculum that other faculty teams can adopt in the future. In addition, it increases the potential breadth of possible projects campus-wide that might benefit from the use of this instrumentation.

The project revealed the critical role lab technicians currently play in undergraduate research. As an institution that does not have day graduate programs (or graduate students and research-based faculty appointments), technicians currently provide both technical assistance and supplemental mentoring to undergraduate students. Based on the results of this project, it appears that lab technicians will need to serve in a role of support to both students and faculty for undergraduate research to grow on campus.

Through dissemination, hundreds of people, including elementary through high school students, undergraduate students of multiple disciplines, practicing professionals from differing disciplines and the general public, have been impacted by learning about the methods of trace metals analysis and the application and interpretation of analytical results. Projects have provided information to a wide range of audiences about clean water and soil, environmental quality, recycling, and the presence of metals in household products. While most of the people reached by dissemination efforts may not become metals researchers, they all stand to have a better understanding of trace metals in ordinary objects and how they may affect life.

This project has already provided initial trace metal analysis training to thirty-nine undergraduate students. It is likely that dozens more students will be similarly trained in the future following the protocols established under this project. These students will graduate and their professional careers will be influenced by what they have learned while performing undergraduate research. Most Wentworth graduates will obtain professional degrees (engineering, science, management and design) and will be influenced by not only the scientific aspects of the projects, but also the service and public outreach aspects of each project.

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