Paper ID #40579

Increasing Global Education Opportunities for Engineering Students: Pilot Collaborative International Project Studying Coffee Wastewater Treatment

Dr. Michael Marsolek, Seattle University
Dr. Katie Kuder, Seattle University

Katie Kuder is Associate Dean and a Professor of Civil and Environmental Engineering in the College of Science and Engineering. Dr. Kuder received her B.S. in Civil Engineering from Gonzaga University in 2000. She earned a M.S. (2002) and Ph.D. (2005) in Civil Engineering from Northwestern University, specializing in Structural Engineering and Materials. Her research area is in cement-based materials, focusing on sustainability. As Associate Dean, she is responsible for global programs in the College of Science and Engineering.

Joseph Pacini
Patricia Jones
Luis Jaramillo Gomez
Manuela Estrada Giraldo
Manuela Torres Giraldo
Juan Camilo Valencia Reyes
Jose Manuel Rangel Gutierrez de Pineres
Zainab Ahmad, Seattle University
Ian Woodley, Seattle University

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Abstract

This paper describes a pilot collaborative international project studying the treatment of coffee wastewater treatment.

Seattle University (SU) and the College of Science and Engineering (CSE) want to expand global engagement opportunities for students and faculty. Additionally, the Office of Global Engagement and CSE aim to develop partnerships with the members of the International Association of Jesuit Engineering Schools (IAJES). However, challenges exist for both students and faculty to participate in global programs. Students face multiple barriers, including potential impacts on time to graduation, cost, and competing summer plans, such as internships and athletics. Faculty teach heavy course loads and limited resources exist to support development of co-curricular activities. This pilot collaborative international engineering project provided a short-term global engagement opportunity for students and faculty that addressed many of these barriers and furthered strategic priorities of the university and the college.

The purpose of this project was to develop a pilot collaborative international engineering project that allowed faculty and students at partner institutions to work virtually and in-residence on a shared research topic. A faculty-student team at SU partnered with a faculty-student team at Pontificia Universidad Javeriana Bogotá (PUJ), a member of IAJES. Their joint research aims to study the treatment of wastewater from coffee processing and to find low-cost solutions for smallholder farms to clean wastewater.

The teams began with virtual collaboration in the spring via Zoom to become familiar with the project, begin initial analyses, and plan exchange visits. In spring, students at SU carried out laboratory work to create synthetic coffee wastewater. PUJ visited Seattle University in early summer to conduct laboratory tests using the synthetic coffee wastewater with granular media and bag filters. Seattle University went to Pontificia Universidad Javeriana Bogotá in late summer to tour coffee farms, see various coffee bean harvesting and water processing techniques, and conduct laboratory tests using the same filters but with real coffee wastewater. Experimental results show that sand filters could significantly improve turbidity but suffer from severe head loss, while the bag filters perform poorly with synthetic wastewater but show promise with real coffee wastewater. Future testing should focus on the use of bag filters as they are easier to install, use, and maintain.

The pilot project was successful in multiple ways. In addition to the technical skills developed, both visits offered rich cultural exchange opportunities to students as they served as both host and also visitor. Students learned about the civil engineering practice in a new culture, while simultaneously working to improve environmental justice, connecting the work to the mission of SU. Students were surveyed after the pilot program was completed to assess its impact on their technical knowledge, changes to their perception of factors for successful science and

engineering projects, and their perception of benefits from the project. The authors hope this pilot project will serve as a framework for future collaborative engineering projects between SU and IAJES partners, expanding global educational opportunities for students and faculty.

Introduction

The professional world has become more globalized, increasing the need for students to be politically and culturally competent, adaptable, and able to solve problems creatively [1] [2]. Global experiences have been shown to significantly improve workplace skills, including increased cultural awareness, improved understanding of global perspectives, and ability to work on diverse teams [3, 4]. Despite these benefits, STEM majors continue to be underrepresented in global programs [3]. Students face multiple barriers, including potential impacts on time to graduation, cost, and competing summer plans, such as internships and athletics [5, 6]. At our institution, faculty teach heavy course loads and limited resources exist to support development of co-curricular activities. While research shows that long-term study abroad provides the most significant gains [7], short term programs have also been shown to effectively achieve global education outcomes [8], while being accessible to more students.

Our institution is a Jesuit, mission-focused university. We are a member of the International Association of Jesuit Engineering Schools (IAJES), which is a new network of Jesuit engineering schools that was formed in 2018. There are approximately 200 Jesuit institutions in the world, with around 55 of those having engineering programs. Our university is interested in expanding global education opportunities for our students, faculty, and staff as well as establishing relationships with other members of the IAJES.

The purpose of this project was to pilot an international engineering program that provided a global education experience for students and faculty that addresses many of the barriers that limit typically limit participation in these programs, while also furthering strategic priorities of the university by increasing global engagement, expanding partnerships with member of IAJES, and enhancing the student experience. A faculty-student team at Seattle University (SU) partnered with a faculty-student team at Pontificia Universidad Javeriana Bogotá (PUJ), a member of IAJES. The project was short-term, reducing cost, allowing students to complete other activities in the summer, including research projects and internships, and not affecting course sequencing. Their joint research aims to study the treatment of wastewater from coffee processing and to find low-cost solutions for smallholder farms to clean wastewater.

This paper presents the project framework, preliminary coffee wastewater treatment research results, and assessment results from student surveys related to identity and professional formation. Results suggest the framework developed can be used for future collaborations, that there is promise with the sand and bag filters, and that students gained an appreciation of the importance of social and cultural factors in real-world projects.

Project Framework

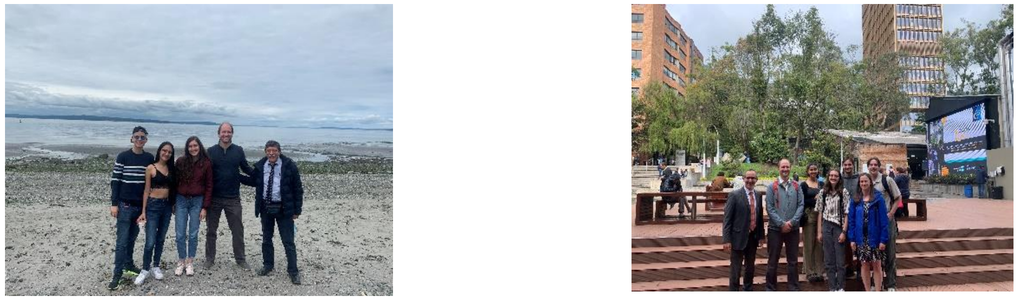
The project timeline is shown in Table 1. The teams worked virtually and in-residence on a shared research topic. Faculty from SU and PUJ with experience working in wastewater treatment and coffee processing were selected to collaborate on this project. Each faculty member recruited undergraduate students to participate. The work began with virtual collaboration in the spring via Zoom to identify project goals and to create a plan to achieve them. Each team then visited the other campus for one week during the summer academic term.

Table 1. Pilot Global Engineering Project Activity Timeline

Activity	**Term**
Bi-weekly Virtual (Zoom) Collaboration	Winter/Spring 2022
Team introductions	
Background research	
Pontificia Universidad Javeriana visits Seattle University	June 2022
Campus tour	
Laboratory filtration tests	
Seattle sightseeing	
Seattle University visits Pontificia Universidad Javeriana	September 2022
Campus tour	
Coffee farm site visits and laboratory filtration tests	
Colombia/Bogotà sightseeing	

Each team had different technical responsibilities. The SU team was responsible for carrying out preliminary filtration tests using a synthetic coffee wastewater, since genuine coffee wastewater is not available locally. The SU team then demonstrated these tests to the PUJ team during their site visit, and they collaboratively assessed filtration performance. The PUJ team investigated common coffee processing techniques in Colombia and identified typical wastewater treatment technologies. They also identified and contacted local farms that they visited during the site visit to Bogotá. Finally, the filtration tests were repeated in PUJ labs using actual coffee wastewater generated from beans collected from the farms.

In addition to the technical research, each team was involved with planning and hosting when the other team visited their campus and with making travel arrangements to visit the partner university. Each visit began with campus tours and included sightseeing, adding to the cultural dimension of the program. Figure 1 shows pictures from these visits, including (a) PUJ students and faculty seeing Golden Gardens, a local site in Seattle and (b) SU students and faculty touring the PUJ campus. There were also meetings with faculty from both institutions to discuss future research and educational opportunities.



(a) (b)

Figure 1. Exchange Visits: (a) Local Sites - Golden Gardens and (b) Pontificia Universidad Javeriana Bogotá

Coffee Wastewater Treatment Background

Coffee farming techniques vary around the globe, with differences in fermentation, depulping, rinsing, and drying. Coffee wastewater is generated from rinsing the fermented beans, to remove the mucilage layer, which would otherwise rot during the drying process. The volume of wastewater generated ranges from 4-20 m^3 per tonne of fresh cherry [9]. Previous investigations by the author with smallholder farms in Nicaragua found that approximately 6 m^3 of wastewater were produced per tonne of fresh cherry [10]. Biochemical Oxygen Demand (BOD) values are very high and range from 5,000 – 20,000 mg/L [11], while pH is low, typically around 4 [10]. The wastewater is highly amenable to biological processing techniques, which are often used at large farms, but they are inappropriate for smallholder farms due to heavy requirements for maintenance and oversight, and they often have recurring costs that cannot be borne by the farmers. Therefore, physical treatment processes such as gravity sedimentation and granular media filtration are appealing for this application.

Research Collaboration

From a technical perspective, the purpose of this collaboration was only to carry out preliminary work identifying appropriate filtration technologies for coffee wastewater. The filtration options analyzed were granular media filters, with nominal grain sizes of greater than 4.75 mm, 2.0 mm, 0.131 mm, and 0.0164 mm. In addition, a 10 µm pore size bag filter (Pentek USA) was tested. Synthetic coffee wastewater was generated by pureeing fermented mango fruit (which has characteristics similar to coffee cherries but is available in the US) and suspending 14 g of the puree per liter of deionized water, with the ratio identified through serial dilution until the target COD of 5,000 mg/L was achieved.

Figure 2 shows how the turbidity of the synthetic wastewater change during ripening of the granular media filters. The smaller grain size filters remove the turbidity faster (1^{st} order kinetic coefficients of 0.028, 0.041, 0.065, and 0.074/min, for 4.75, 2.0, 0.131, and 0.0164mm grain sizes, respectively). In addition, the steady-state removal increases as grain size decreases, with effluent turbidity C/C_0 = 26 ± 3% for the 4.75 mm filter, 16 ± 2% for the 2.0 mm filter, 7 ± 3% for the 0.131 mm filter, and 6 ± 1% for the 0.0164 mm filter. Hydraulic loadings are 0.37 m/hr for the two larger grain-size filters, and 0.15 m/hr for the two smaller grain-size filters. This is near a typical hydraulic loading for slow sand filters of 0.05-0.2 m/hr [4]; however, we would expect the loading rate to decrease as the filters ripen, and the two smaller filters experienced severe head loss during the trials. The bag filter do not remove turbidity to an appreciable level using the synthetic wastewater.

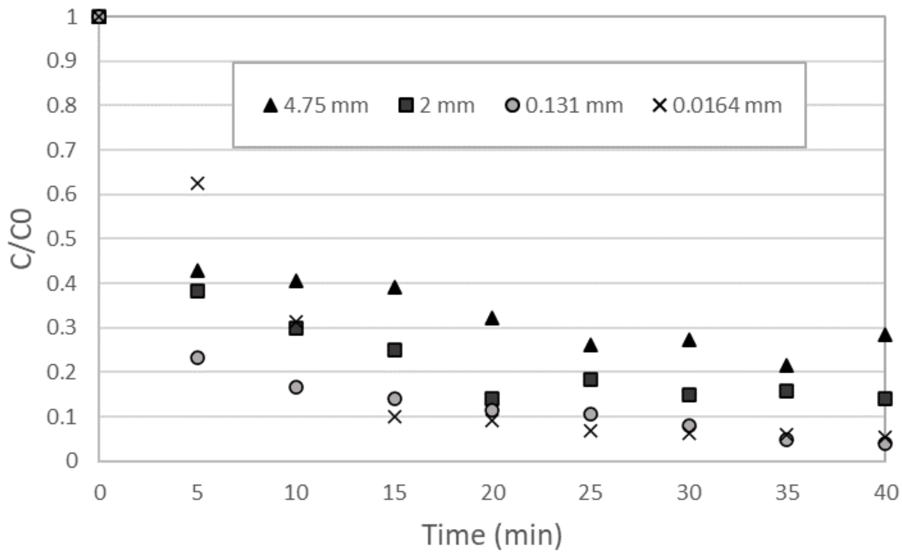


Figure 2. Changes to turbidity concentration, normalized to initial NTU, over time for varying sized granular media. Smaller grain-sizes correlated with faster turbidity removal and lower stabilized effluent turbidity, though head loss was severe.

In Colombia, the team toured multiple farms and various wastewater treatment processes. At one of the farms, they picked coffee cherries and brought them back to campus for testing. Figure 3 shows experimental testing conducted at PUJ after the field visits. Testing at PUJ using actual coffee wastewater was assessed via total solids analysis. The 0.131 mm filter removed 47% of total solids, and the bag filter removed 13% of total solids. The 2.0 mm filter did not remove total solids to any appreciable degree.

(a) (b) (c)

Figure 3. Experimental Testing as Pontificia Universidad Javeriana Bogotá: (a) removing cherry coffee mucilage layer, (b) total suspended solids test, and (c) filtration tests.

Experimental results show that sand filters could significantly improve turbidity but suffer from severe head loss, while the bag filters perform poorly with synthetic wastewater but show promise with real coffee wastewater. Future testing should focus on the use of bag filters as they are easier to install, use, and maintain.

Project Assessment

Socio-technical engineering perspectives can be readily formed through humanitarian engineering projects, particularly through service-learning design [12]. Bielefeldt and Canney [13, 12] found that service-learning courses, Engineers Without Borders (EWB) projects, and service trips benefitted engineering student's attitudes on social responsibility, though selection bias of students who chose those projects also implicitly affects results. Park et al. [14] found that students who envision themselves as humanitarian engineers were associated with their socio-cultural background, motivation to place engineering skills into practice, and interest in travel. A limited triangulation design: convergence model [15] approach is used here to assess the impact of this service-learning project on student participants identity and professional formation. As a preliminary analysis, a written survey was used for the participants and non-participants in the same cohort (junior standing) at SU, and interviews were used for the participants. Future analysis will include the PUJ participants and non-participants from their cohort.

Team members (TM, n=3) and non-participants (NP, n = 16) were asked on a Likert scale of 1-5 (1 = strongly disagree and 5 = strongly agree) to score questions related to sociotechnical competency, as shown in Table 1. Results generally track for both groups, including scoring *I would feel confident integrating the concerns of non-engineers into my design project* lowest among the eight questions. The only difference of note is the students participating in the pilot project (TM) score their desire to work outside the USA at some point in their career at a 5, whereas TP score this at 4.1 ± 0.6.

Table 2. Assessment results from pilot collaborative international research project. Team member and non-participant scoring of questions related to sociotechnical competency (adapted from [16]).

Question	**Team Member Score (n=3, avg ± 95% confidence interval)**	**Non-Participant Score (n=15)**
1. I desire to learn about new people, places, and cultures.	5.0 ±0	4.7 ± 0.2
2. It is easy for me to see others' points of view.	4.3 ± 0.7	4.0 ± 0.4
3. It is important to integrate the concerns of users into a design project.	5.0 ± 0	4.5 ± 0.3
4. I would feel confident integrating the concerns of non-engineers into my design project.	4.0 ± 0	3.8 ± 0.2
5. I enjoy working with scientists and engineers having different backgrounds than my own.	5.0 ± 0	4.3 ± 0.4
6. I would like to work outside the USA at some point in my career.	5.0 ± 0	4.1 ± 0.6
7. I would like to work on projects that serve underprivileged populations.	4.3 ± 1.3	4.5 ± 0.3
8. I can make positive social change through science and engineering.	5.0 ± 0	4.6 ± 0.3

When asked how students *perceived their role as an engineer in regard to the customer*, the only characteristic identified by all three TM was the need to meet stakeholder concerns, also a recurring theme during the interviews. This characteristic was also noted by 50% of the NP group, indicating that students generally perceive their role as meeting the needs of the client, and the service-learning project emphasized its importance to the team members.

Both groups were also asked to rank eight factors in terms of *importance to a successful science or engineering application*, with 1 being most important and 8 being least important. Results are shown in Table 3. Both groups scored *communication* and *teamwork* among the top three factors. TM ranked *organization* at #2, whereas NP ranked it at #5, however the average ranking was not significantly different at the 5% level (p = 0.27). TM ranked *social and cultural awareness* at #4, NP ranked it at #7, and the average ranking was significantly different at the 5% level (p=0.04), This indicates that the international service-learning experience had a strong impact on student's perception of the importance of social and cultural factors to a successful project, fulfilling one of the goals of a sociotechnical curriculum.

Table 3. Assessment results from pilot collaborative international research project. Team member and non-participant ranking of factors influencing successful science and engineering applications. Numbers in parentheses indicate relative placement from 1-8, with 1 being identified as most important on average.

Question	**Average Team Member Ranking (n=3, avg ± 95% confidence interval)**	**Average Non-Participant Ranking (n=14)**
Organization	3.0 ± 2.3 (#2)	4.2 ± 1.5 (#5)
Technical Knowledge	4.7 ± 3.5 (#5)	3.8 ± 1.0 (#3)
Empathy	6.3 ± 1.7 (#7)	6.4 ± 0.7 (#8)
Leadership	6.7 ± 0.7 (#8)	5.0 ± 1.0 (#6)
Communication	1.7 ± 1.3 (#1)	2.9 ± 1.1 (#2)
Teamwork	3.7 ± 1.7 (#3)	2.9 ± 0.7 (#1)
Experience	6.0 ± 3.0 (#6)	4.2 ± 0.9 (#4)
Social and Cultural Awareness	4.0 ± 2.3 (#4)	6.1 ± 0.8 (#7)

Interviews reinforced some conclusions from the surveys. All three team members indicate that working in a team and experiencing a new culture as two of the three most important benefits of the program. When asked how the program prepared them for professional practice, two out of three team members indicated that working on a real-world research project outside of a controlled classroom setting will benefit them. When asked how the project influenced their view of stakeholders, two out of three indicated the visits to actual farms were particularly beneficial in helping them understand that solutions must be adapted to the specific community being served, reinforcing the concept of culturally appropriate technologies.

Conclusion

The pilot international collaborative project was successful. In addition to the technical research and communication skills developed, both visits offered rich cultural exchange opportunities to students as they served as both host and visitor. Students learned about the civil engineering practice in a new culture, while simultaneously working to improve environmental justice, connecting the work to the mission of SU. The institutions successfully collaborated together - faculty successfully completed a research project and opportunities were provided for additional faculty networking. The experimental results show that low costs filters (both sand and bag filters) show promise, but that more testing is needed, particularly with bag filters that are easier to install, use, and maintain. Finally, assessment results show that the students that participated in the project were more interested than their peers in working outside the US and had a greater appreciation of the importance of social and cultural factors to a successful project.

References

[1] L. H. Jamieson and J. R. Lohmann, "Creating a Culture for Scholarly and Systematic Innovation in Engineering Education: Ensuring U.S. Engineering Has the Right People with the Right Talent for a Global Society," in *American Society of Engineering Education*, Washington DC, 2009.

[2] N. A. o. Engineering, "The Engineer of 2020: Visions of Engineering in the New Century," National Academic Press, Washington, DC, 2004.

[3] C. Farrugia and J. Sanger, "Gaining an Employment Edge: The Impact of Study Abroad on 21st Century Skills & CAreer Prospects in the United States," Institute of International Education, 2018.

[4] T. M. Chowdhury, H. Murzi, K. D. M. Soto and A. Schuman, "Measuring the Impact of a Study Abroad Program on Engineering Students' Global Perspective," in *ASEE Annual Conference and Exposition*, 2021.

[5] J. M. Grandin and D. Hirleman, "Education Engineers as Global Citizens: A Call for Action/A Report of the National Summit Meeting on the Globalization of Engineering Education," *Online Journal for Global engineering Education,* vol. 4, no. 1, pp. 1-28, 2009.

[6] A. Parksinson, "Engineering Study Abroad Programs: Formats, Challenges, Best Practices," *Online Journal for Global Engineering Education,* vol. 2, no. 2, pp. 1-15, 2007.

[7] M. E. Besterfield-Sacre, G. R. Ragusa, C. Matherly, S. Phillips, L. Shuman and L. Howard, "Assessing the Spectrum of International Undergraduate Engineering Educational Experiences," in *American Society of Engineering Eduction Conference and Exposition*, 2013, 2013.

[8] D. B. Knight, K. A. Davis, K. J. Timothy, C. Twyman and A. M. Ogilvie, "The Rising Sophmore Abroad Program: Early Experiential Learning in Global Engineering," *Advances in Engineering Education,* vol. 7, no. 3, 2019.

[9] M. Sas, "Eco-Engineers Treatment of Coffee Wastewater According to the Waterharmoniz: A Case Study in Matagalps, Nicaragua," *Wageningen (Netherlands): Aqua for All & LEAF,* May 2006.

[10] M. D. Marsolek, P. K. Cummings, J. T. Alcantara, M. Wynne, L. F. Quintero, C. Vallejos, C. F. Jackels and S. C. Jackels, "Wasterwater Treatment for a Coffee Processing Mill in Nicaragua: A

Servce-Learning Design Project," *International Journal for Service Learning in Engineering,* vol. 7, no. 1, 2012.

[11] J. C. von Ended and K. C. Calvert, "Review of Coffee Waste Water Characteristics and Approaches to Treatment," German Technical Cooperation Agency, 2002.

[12] J. L. Huff, C. B. Zoltowski and W. C. Oakes, "Preparing Engineers for the Workplace Through Service Learning: Perceptions of EPICS Alumni," *Journal of Engineering Education,* vol. 105, no. 1, pp. 43-69, 2016.

[13] A. R. Bielefeldt and N. Canney, "Impacts of Service-Learning on Professional Responsibility Attitudes of Engineering Students," *International Journal for Service Learning in Engineering,* vol. 9, no. 2, pp. 47-63, 2014.

[14] J. J. Park, M. Park and J. Smith, "Engineering Students' Concepts of Humanitarian Engineering and Their Identity Development as Humanitarian Engineers," *Sustainability,* vol. 13, no. 8845, 2021.

[15] J. W. Cresswell and V. Clark, Designing and Conducting Mixed Methods Reserach, Sage Publishing, 2017.

[16] J. M. Smith, J. Lucena, A. Rivera, T. Phelan and K. Smits, "Developing Globabl Sociotechnical Competancy Through Humanitarian Engineering: A Comparison of In-Person and Virtual International Project Experiences," *Journal of International Engineering Education* , vol. 3, no. 5, 2021.