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Steeped in Engineering: Using coffee to introduce students to engineering

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Steeped in Engineering: Using coffee to introduce students to engineering at the University of Washington Tacoma

Abstract

In 2022 the University of Washington Tacoma launched a new introduction to engineering course focused around coffee. The course has been designed to support recruitment and retention with an emphasis on building community. The course is part of the larger ACCESS in STEM program at the institution designed to support student pathways in STEM fields. The first offering of the course was successful and we present an outline of the course for possible adoption by other institutions.

Introduction

Students with intersection identities are less likely to graduate with STEM degrees due to system barriers in higher education [1], [2]. To address these barriers, institutions need to take a holistic approach and recognize the strengths that economically disadvantaged students bring– shifting to an asset-based mindset [3]. Nationally, only 20% of undergraduate engineers and computer scientist degrees are awarded to women, and only 6% are women of color [4]. Black/African American, Hispanic, and Native American students earned 16.1% of bachelor's degrees in 2018.

The University of Washington Tacoma (UWT) recently entered Phase 2 of its NSF-funded "Achieving Change in our Communities for Equity and Student Success (ACCESS) in STEM" program in 2022. The National Science Foundation will fund the program with a $1.5 million grant over the next 7 years. ACCESS in STEM recruits talented students, primarily with low income or underrepresented backgrounds, to study one of UWT's STEM majors, and seeks to support their retention and academic success by providing focused mentoring, a living learning community, course-based undergraduate research experiences, and two years of targeted scholarship support [5], [6]. Phase 2 represents an expansion of Phase 1 in terms of additional eligible majors, inclusion of first-year transfer students, and the definition of "low-income" will be broadened to include students in the "middle zone." All engineering majors at UWT, including Computer, Electrical, Mechanical and Civil are now eligible to apply for the program. Mechanical and Civil Engineering are two of the newest engineering programs, starting in 2021 and 2022, respectively.

As part of the second phase, a new introductory course was developed and offered for the first time in Autumn 2022. This project-based Introduction to Engineering course leveraged best practices from engineering education to engage students in their academic careers. The course was inspired by the successful coffee-based class pioneered at UC Davis, which has been used at other universities to support students [7]. The class was and will continue to be available to all first-year UWT students, with a priority for ACCESS students during registration. In addition to providing students a glimpse into the various concepts in engineering, the course was developed to create a sense of community and also provide a support structure for students wanting to pursue engineering. The course content used evidence-based practices to connect students with hands-on experiences and learning. First year engineering courses, when well designed, have been shown to offer many benefits to student retention [8], [9].

The course was designed with several specific goals:

1. Recruit students in engineering that might not otherwise be aware of the profession.
2. Build community and connections to the institution and faculty that will support student retention and degree progression.

Course Content

While the course is titled *Introduction to Engineering*, it differs from most introductory engineering courses offered in many institutions across the country. One thing to note is that the University of Washington (UW) has traditionally not been a direct admission institution at the undergraduate level. The School of Engineering and Technology (SET) at UWT will be offering direct admission starting in the 2023-24 academic year. Therefore, a vast majority of first-year students at UWT are either undecided or have not gained acceptance into the program of their choice yet. While this course is designed to support students that intend to major in the various engineering fields, it is also used as a way to recruit students that have never been exposed to engineering prior to attending UWT. A summary of the way the course is positioned in the institutional context is shown in Figure 1.

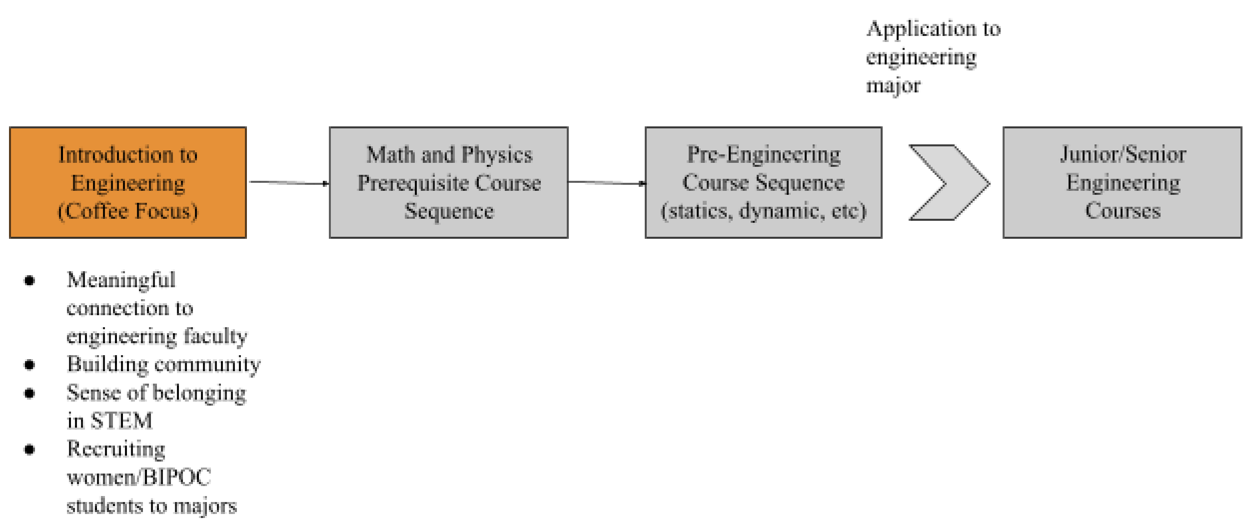

Fig. 1. Institutional context for the coffee course. This class is an important way to connect students to faculty and engineering majors before they tackle the pre-requisite course sequence.

Given this context, it was important for faculty to design an introductory course that describes the engineering profession and helps students analyze data that exposes them to the different engineering disciplines, while at the same time do it in a way that is relatable, builds community, and focuses on environmental and social impacts. UWT has a unique student demographic; in the 2022-23 year, 54% of undergraduate students are first-generation, 34% are underserved students of color and 41% are Pell grant-eligible. Therefore, many students, including those that intend to major in engineering, have had limited exposure to advanced math and science courses in high school.

Coffee production and roasting involve various types of equipment which involve mechanical, electrical and even chemical and environmental engineering and the coffee bean roasting involves heat transfer, an important mechanical engineering topic. The way products get distributed from farm to table involves several parts of the supply chain, which is a core aspect of civil engineering. A cup of coffee that so many of us enjoy every morning requires significant types of engineering to provide the end result. Given the various ways coffee relates to the different fields of engineering, the course introduces the basics of engineering through the exploration of coffee. It focuses on various aspects of coffee from an engineering perspective including coffee production and brewing, coffee economics, environmental sustainability, social responsibility, reverse engineering and coffee chemistry.

The first part of the course covers the basic statistics of coffee related to popularity, consumption and commodity trading as well as its global history starting in Ethiopia up to Starbucks. More interestingly and of importance to engineering, the focus shifts towards coffee extraction and roasting, where students learn coffee plant varietals and relative caffeine content and how origin, climate, altitude and extraction process all affect the taste of the final coffee drink. Coffee roasting is where significant engineering and chemistry is discussed, where students learn about endothermic and exothermic reactions involving heat transfer and pyrolytic processes resulting in the transformation of the coffee bean from light to dark roasts. Finally, we discuss the various coffee solubles, such as acids, caffeine, lipids, fats, melanoidins, carbohydrates and fiber, and how they affect the distinct flavor notes. This discussion also includes lessons on calculating the Total Dissolved Solids (TDS) (a measure of how much coffee is dissolved coffee solids) and extraction percentage (what percent of coffee grounds' mass ends up in a cup). This helps them understand a scientific method to determine under, over and optimal extraction.

The course also includes a number of hands-on lessons and activities. One of those was learning to produce a pourover drink and how to intentionally produce an under, over and optimally extracted drink. Figure 2 shows the equipment used to both perform this activity.

Fig. 2. Equipment used to produce pourover drinks (Left to right: Kettle, V60 dripper, Chemex)

In addition to pourover drinks, students learned to explore taste notes of various coffee beans via cupping. Cupping is a popular method, similar to wine tasting, that is used by experts and coffee enthusiasts to identify taste notes in new coffee beans or to develop their knowledge of various coffee beans and varietals. Figure 3 shows the layout for a cupping session identical to the one performed in a recent class. Three cups of each type of coffee was brewed and placed in a group. In the first part, the bags were hidden and students were asked to identify the notes they were tasting. In the second part, one out of the three cups in each group was switched with another and students were asked to identify the odd one out.

Fig. 3 Cupping demonstration

The class also included visits to various local coffee shops, where students saw first-hand how coffee beans get roasted and perfected into various coffee and espresso-based drinks (Figures 4 and 5). Other experts visited the classroom to deliver guest lectures on their business models and philosophy behind producing high-quality, socially and environmentally responsible coffee.

The coffee shop visits were one of the important aspects of building community in the class. Students took public transportation (free with student ID cards) and learned to navigate the city to several coffee shops. Riding the bus and getting to know the community near the university is important to help students develop a sense of belonging at the institution. Spending time informally to walk or ride to new coffee shops gives students an opportunity to chat informally with one another and the course professor.

Fig. 4 Class visit to Valhalla Coffee in Tacoma, WA

Fig. 5 Class visit to Dancing Goats in Tacoma, WA

For their final projects, students have a chance to perform a hands-on disassembly of a coffee machine. In our first run, students were tasked to develop a bill of materials based on weighing and identifying individual components and materials. They were also tasked to perform a disassembly analysis whereby they suggested possible improvements in design to increase the efficiency of the disassembly and recycling process. This connection allowed students to experience elements of the engineering research process with a faculty member based on prior work in sustainable design and life cycle assessment [10]–[12].

The following is the list of tasks (along with Tables 1 and 2) that students were required to complete:

1. It will be helpful to designate roles for each group: lead, notetaking, disassembly, timekeeping and weighing.
2. Observe your coffee machine and discuss with your groups members how you think the machine operates, as well the design aspects. Also take note of any specs or details that might help you search for more information on the internet.
3. Take photos of your machine before, during and after disassembly. These will be helpful when discussing the process and recommendations.
4. Before you begin disassembling, remember that you will be commenting on the materials, components, fasteners, mass and ease of disassembly of your machine. Consider these throughout the disassembly activity.
5. Start your disassembly. To help you collect the relevant data, a bill of materials is attached to this sheet. You are to identify individual parts and the corresponding material,

mass, whether it's recyclable, time and the recycle fraction based on material factors provided below.

6. Repeat step 5 until you've disassembled as much as you can to separate individual materials from each other.
7. After the disassembly, spend time with your group performing a "postmortem" of the machine. Discuss elements of the disassembly process, its ease or lack thereof, operational aspects that weren't apparent initially, etc.
8. Prepare to compile information for your presentations. Presentations will be 10-15 minutes long and each group will present their analysis of the design, functionality, disassembly and redesign of their coffee machine.

Table 1. Material Recycling Fractions

Material	**Recycle Fraction**
Steel	75-85
Copper	35-85
Zinc	35-85
Aluminum	85
PC/ABS (Polycarbonate/acrylonitrile butadiene styrene) (Industrial plastic)	15-55
PS (Polystyrene)	15-55

Table 2. Data collection table with example

Part	**Material(s)**	**Mass (lbs.)**	**Recyclable (Y/N)**	**Disassembly time (mins and secs)**	**Recycle Fraction**
Ex. Steel Screw	*Steel*	*0.11*	*Y*	*11 secs*	*75-85*
	Total Mass		**Total Time**		

Conclusions

While this class is still under development, the initial offering was well received by students and we plan to continue offering the course. An informal survey of students at the end of the course indicated that a significant number of students were initially unaware of and intimidated by engineering as a major, but eventually learned how it can spark curiosity and engagement. This sentiment significantly helps us recruit students into engineering. Students enjoyed the field trips and the opportunity to deconstruct a device that most of us take for granted - a great way to learn about engineering. These activities were a big part of building community and connections to UWT, the faculty and local community. Future work will focus on quantifying the way students connect with the engineering profession and the community as part of the class.

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