Weaving Internship Experience into an Engineering Education Module

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***Abstract*—This Innovative Practice Work in Progress focuses on the development and deployment of an educational module about air quality for upper-division undergraduate engineering students. In a *Photovoltaic Solar Energy* course, one student developed and deployed a module to help other students consider the environmental impacts of engineering projects. This work capitalized on a unique opportunity for the student to bring her knowledge gained in an internship into the classroom to share with her peers. In this paper, the authors describe the motivation for this work, the design and implementation of the module, student responses on a homework and feedback survey, and their own reflections. Students were successful at completing the homework assignment where they applied knowledge gained from the module to a realistic, hypothetical engineering project on their University's campus. Responses from the survey reveal that students felt peer-teaching was valuable and they particularly enjoyed hearing a peer's perspective. Some students valued the specific content of the module, such as working with real environmental data. Others cited learning about diverse leaders who have contributed to the environmental movement around the world. This module could be useful for other classes where instructors are interested in integrating environmental, social, and technical concepts related to sustainability into their curriculum.**

Keywords—air quality; CEQA; environmental engineering; environmental racism; peer-instruction; sustainability

I. Introduction

Engineering Education leaders have long called for educators to move beyond a restricted focus on technical material to understand a larger context. A deep understanding of context and related skills is fundamental for students' long-term success, especially when professional practices deal with difficult and often trans-disciplinary challenges such as those that involve environmental or social justice [1-5]. University of San Diego (USD) is a faith-based, private institution with an Integrated Engineering department that aims to help students see this larger context throughout the curriculum.

The first author, who, at the time of this work, was a fourth year Integrated Engineering major in the Honors Program with an emphasis on Sustainability at USD with several years of professional engineering experience during summer and intersession internships, had a recent engineering internship related to sustainability in which she applied this broader context and wanted to share her experience with others.

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For her honors thesis, the student was mentored by the second author, a tenured engineering professor in the Integrated Engineering department with expertise in Electrical Engineering, Materials Science, and a commitment to making course content relevant to students. Collaboratively, the authors developed a module for the student to teach in one of the professor's classes as a part of her thesis in Spring 2022.

Weaving together knowledge gained outside of the classroom with lessons learned in classes at USD related to environmental and social justice, such as Dr. Christopher Carter's *Faith and Environmental Justice* [6], Dr. Carter and Dr. Andrew Tirrell's *Conceptions of Nature: Race, Faith, Food, and Politics* [7], and Dr. Diana Chen and Dr. Zhi-Yong Yin's *Cities and Urban Design* [8], the first author was able to bring her broad perspective to a class taught by the second author. Through creating this module, the authors had the opportunity to explore the effectiveness of peer teaching for engineering students. Peer teaching is an instructional technique which promotes student interaction, problem-solving, and in-depth learning in the classroom. [9]. This instructional method provides a space for students to incorporate personal experiences from outside the classroom in a way that adds value to the class content.

In section II, the authors discuss the content of the module and the first author's relevant internship experience. Section III will describe the design and implementation of the module, while section IV will consider how students performed and responded. Section V will include the authors' responses and lessons learned, and section VI will conclude this paper.

II. Importance of Air Quality

Air quality is a significant global concern because it can have serious toxicological impacts on both human health and the health of our shared environment. During a public virtual event hosted by the U.S. Green Building Council conducted on February 24, 2022, Holly Hill, Senior Sustainability Program Manager at Southern California Edison (SCE), stated that, "air quality is the backbone of sustainability." A commonly used engineering definition of sustainability, from the Brundtland report, is: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [10].

Engaging with the environmental issue of air quality from a variety of intersectional perspectives can play a key role in our pursuit of truly sustainable development. The first author was able to practice this in an internship in Summer 2021. As an Air Quality intern for the electric utility company SCE, the student author learned that several different emission sources result in air pollution, but that fossil-fueled vehicles and industrial processes tend to contribute most. Long- and short-term exposure to air suspended pollutants is strongly correlated with respiratory and cardiovascular diseases, neuropsychiatric conditions, and cancer; several reports from the World Health Organization (WHO) reveal a direct association between exposure to poor air quality and an increasing rate of mortality [11-14]. Specifically, communities populated primarily by People of Color and members of low-socioeconomic backgrounds are burdened with disproportionate amounts of environmental pollution that not only lower the air quality they are exposed to but also their quality of life [15, 16]. After learning about this reality in her classes at USD and witnessing this play out in her own communities, the student author was convinced that she needed to use her position of power and privilege to fight environmental racism. One way that she thought she could do this was through empowering others to fight environmental racism in their own communities.

As a part of her internship project, the first author learned to engage with specific tools that are commonly used to quantify air pollution and air quality, such as CalEnviroScreen [17], California Emissions Estimator Model [18], and Microsoft Excel. Using real data, she improved air pollutant and greenhouse gas tracking for California Air Districts to support compliance frameworks and inform corporate reports. A subset of the skills that she learned in her internship she hoped to help her classmates develop for their own sustainability-related career journeys. A few weeks after her internship ended, she was tasked with formulating a year-long capstone project for her honors thesis. Consequently, she decided to focus her thesis on teaching her peers about what she learned at her internship with SCE. Her academic advisor and honors thesis advisor, who is the second author of this paper, provided guidance and mentorship, and collaboratively, they designed and implemented a module in one of the second author's classes.

III. Design and Implementation

A. Course Logistics

Photovoltaic Solar Energy is an elective class for Integrated Engineering majors taken in the third or fourth year. In Spring 2022, this module was implemented in this course with 14 students in week 9 of a 15-week semester. This was the first offering of this course. Students worked in semester-long cooperative learning homework teams to complete weekly assignments, and this module made use of these teams. The module activities were part of the required elements of the class, and informed consent was obtained for participation in a voluntary survey after the module. The "Air Quality" module was designed to include several activities as shown in Table I and the authors are happy to share these resources.

TABLE I. Activities in Air Quality Module

Class	Homework (Group)	Homework (Individual)
Presentation on Air Quality, SCE, and CEQA; Discussion	Weekly Homework Assignment: explore and reflect on BIPOC voices; research and conduct emission calculations	Reflection on Importance of Module to Engineering and Voluntary Feedback Survey (Google form)

B. Goals

Using a backwards design methodology [19, 20], the authors developed these learning objectives for the module:

- Explain what criteria air pollutants and greenhouse gases are along with their primary sources and effects
- Given emission factors and usage data, calculate air emissions and determine the carbon offsets required to achieve carbon neutrality
- Explain how improving emission estimates can impact people, the planet, and profit
- Use public data to evaluate the environmental impact of an active construction project
- Describe the history of environmental regulations from multiple intersectional lenses
- Provide two or three examples of why critically reviewing and interpreting environmental legislation such as the California Environmental Quality Act (CEQA) is a valuable skill for an Engineer to have

In designing this module, the authors wanted to ensure that the environmental context and technical content worked together in helping students see engineering as a multidisciplinary endeavor. By challenging the often-perceived binary between social and technical matters, the module aimed to break this socio-technical divide that exists within engineering education [21].

Working as a team, the authors met weekly throughout the Fall 2021 and Spring 2022 semesters to develop technical calculations in addition to an oral presentation and guided discussion. Throughout this process, the authors kept in mind that the environmental and economic aspects of sustainability are often prioritized over its social counterparts in engineering classrooms [22]. Therefore, another important consideration was that the authors wanted to provide students with a sense of whose voices have historically been heard in discussions about environmental issues such as air quality, while emphasizing the social implications of the issue. As a result, the authors intentionally tried to uplift the voices of Black, Indigenous, and People of Color (BIPOC) throughout their module.

The authors also wanted to help students begin to appreciate the technical complexity of quantifying air quality without overwhelming them. Thus, the authors sought to help them connect this multidimensional topic to their everyday lives as contributors to their environments. The authors wanted to expose them to a strategy that a specific company, SCE, used to measure and address the issue of air quality, and the student instructor shared her experience working as an Air Quality Intern at the company to increase student interest in this module.

C. Class: Student Instructor Presentation, Worksheet, and Discussion

The class began with the student instructor explaining that she was teaching the class session as a part of her honors thesis work. She then provided an overview of a recent internship experience, explaining that her project served as inspiration for the module. Students were then introduced to the topic of air quality and its relevance to environmental justice issues locally by examining geographic information systems (GIS) maps of air pollutants and demographics data from the most recent census so that they could make the connection to environmental racism in San Diego [23]. A brief history of environmental regulations in the USA beginning in the 1960s with Rachael Carson's *Silent Spring* [24] illuminated the social issue of whose voices have historically been heard and whose have been ignored, if not silenced [25]. This led to a discussion of relevant historical context for major environmental regulations from multiple intersectional lenses. The works of Wangari Maathai [26] and Leah Thomas [27-29] were highlighted.

Then, the student instructor shifted the focus of the class to a California law known as the California Environmental Quality Act (CEQA). Following an overview of its importance for environmental-related careers as well as its primary purposes, students were introduced to a handful of public opportunities for participation in projects governed by CEQA and encouraged to participate in them in the future. Students then learned about ways that companies can reduce their environmental impacts using emission offsets such as carbon offsets and emission reduction credits (ERCs), as well as their key differences [30]. Tying all these pieces together, the student instructor then described a construction project that she focused on during her internship, the Alberhill System Project.

Students were instructed to work in teams to complete a worksheet about this project, which had questions about the air emission calculations performed for the project and made available to the public on the California Public Utilities Commission (CPUC) website [31]. As students worked together in their teams, the student instructor provided context for and answers to the questions incrementally to ensure understanding of the content. At the conclusion of the worksheet, the students reflected on the environmental impacts of fossil fueled heavy-duty vehicles used during the construction project and compared this to a potential solar panel installation project on USD's campus.

Upon completion of the worksheet, the student instructor guided a group discussion that encouraged students to reflect on the assumptions that air emission estimations rely upon, to consider how emission offsets play a role in emission estimations, and to think critically about how emission estimates can impact the environment and local community members in addition to a company's profit margin. Students were then encouraged to reflect upon how they can play a role in influencing the projects that are impacting their own communities.

D. Homework

As part of their weekly homework assignment, each of the four student homework teams, excluding the student instructor, were assigned three homework problems in addition to a reflection prompt, shown in Fig. 1, as well as a voluntary survey that was to be completed individually.

Group Homework Questions

1) The environmental movement is typically discussed through a white lens with a focus on white voices. Do some research of your own on influential Black, Indigenous, and People of Color (BIPOC) leaders in the environmental movement. Briefly discuss two of the leaders that you found in your research (they cannot be the leaders that we discussed in class) and what some of their contributions to the environmental movement were/are. Remember to cite your sources. What steps can you take to support BIPOC voices in the environmental movement?

2) List the six criteria air pollutants and describe the main features of at least two (sources/causes, health concerns, environmental effects, etc.). Feel free to do research beyond what we talked about in class and remember to cite your sources.

3) a) USD plans to become carbon neutral by 2035. Using the general equation for calculating emissions that we discovered in class, calculate the NOx emissions in metric tons (MT) for four bucket trucks operating on our campus given the following information (be mindful of units):

- Number of Trucks Used = 4
- NOx Emission Factor = 0.186 lb/hr
- Usage per Truck = 720 minutes/day for 365 days
- Applicable Conversion Factor = 453.6 g/lb NOx per 1,000,000 g/MT NOx

b) Calculate how much it will cost for USD to offset these emissions using the Terrapass website's rate of $11/metric ton, as mentioned in the Energy Master Plan (pg. 51). If USD purchased $4500 of carbon offsets, would this be enough to offset the carbon emissions from the bucket trucks? Would USD be purchasing these carbon offsets from a conservative or optimistic standpoint? What would you recommend USD does?

Individual Reflection Prompt

Write a 1 paragraph (minimum of 250 words) reflection of what you have learned about air quality and environmental regulations and how it's relevant to you as an Engineer. Incorporate the following terms and their relationship to each other:

- California Environmental Quality Act (CEQA)
- Criteria Air Pollutants
- Natural versus Anthropogenic Pollution
- Emissions Estimates
- Emissions Offsets

Fig. 1. Group and individual homework assigned after Class.

IV. Student Response and Assessment

A. Group Homework

All homework teams received full credit for the first two group homework problems. On the third problem, two teams made a unit conversion error, one team did not answer the question completely, and the last team received full credit. Therefore, all groups received high marks for this portion of the module.

Overall, students' discussions of influential BIPOC leaders in the environmental movement as well as actions they can take to support BIPOC voices demonstrated critical thinking. The BIPOC leaders discussed by students included: Hazel Johnson, Paola Carvajal, Donna Chavis, Nella Frierson, Vandana Shiva, Charles Young, and Robert Bullard. One group described a variety of actions that can be taken to support BIPOC voices.

> We can hire BIPOC…ensure a non-hostile and supportive space…decenter mainstream climate narratives…spread anti-racism around us…[and] use whatever privileges we have to amplify those who don't benefit from the same systems we do.

The level of detail and passion demonstrated in typed student responses regarding the importance of uplifting BIPOC voices in and outside of the environmental movement suggest that this topic engaged and was relevant to students.

B. Individual Homework: Reflection and Survey

All students (excluding the student instructor) responded to an electronic survey after class. All students reported learning new information with 6 (46%) saying they knew 30% or less of the module's content before the class, 3 (23%) reporting they knew between 31% and 50%, 3 (23%) responding they knew between 51% and 80%. One student (8%) did not provide a percentage but indicated in their response that they knew very little of the module's content before peer instruction.

In response to the prompt, "What features of this module and its instruction helped you learn?" 5 (38%) wrote about working with real data in a real-world example, 4 (31%) the presentation, 3 (23%) working in teams and the group discussion, 3 (23%) the pair of GIS maps shown during the presentation, and 2 (15%) the homework.

When asked to reflect on their attitude towards peer-taught engineering instruction and its impact on their learning of concepts explored in the module, 11 (85%) provided entirely positive feedback, and these students noted why they particularly found the module engaging and important.

> Learning from a peer helps to put into perspective that we can have expertise even as undergraduates and can be ready for the workforce…A peer seemed more willing to discuss explicitly the social and cultural issues around engineering problems.
>
> Peer-taught engineering instruction is a great way to get the class involved.

These student responses suggest that peer-teaching in engineering classes as well as our efforts to integrate environmental and social considerations into a technical engineering curriculum have been successful.

V. Instructor Responses and Lessons Learned

Highlights of the experience for the authors included student enthusiasm for engaging with the topic, student insights from their research and reflections, and tying the module's social and technical content together so that students felt the module enhanced their learning of engineering concepts.

One major challenge that the authors faced included deciding on an appropriate level to discuss the socially, environmentally, and economically complex issue of air quality. Identifying and discussing the most important concepts without going into too much detail was critical in maintaining student interest and engagement as demonstrated by student feedback. One student wrote that because of the level at which the content was communicated, they were able to easily understand and absorb the information being taught by their peer. Another wrote that they wanted to learn more about marginalized groups that have helped to increase awareness around environmental racism and intersectionality. The instructors were also moved when another Engineering professor came to observe the module and provided feedback.

> The idea to present a case study from real work experience was very innovative. It was tremendously valuable in giving engineering students an example of what some real engineering work might look like … As someone who teaches a Sustainability and Engineering course, I can definitely see this fitting in to help students understand the different pillars of sustainability in a real context. This case study ties together carbon emissions, life cycle analysis, and renewable energy, as well as the sociopolitical considerations that play a role in sustainability.

Although this module was conducted in a course focused on solar energy, the authors believe it has potential to be effective in sustainability and environmental engineering classes. More substantial in-person discussions can be built into future iterations, as this pilot module was restricted by class constraints. Some students suggested that one way to improve the module would be to have it be longer. For this iteration, the authors provided a simple survey and reflection prompt rather than an extensive assignment to enhance participation. It was encouraging that students responded positively to the module, particularly that they felt it mattered to them as engineers.

VI. Conclusions

A module on Air Quality was successfully implemented into an elective course on *Photovoltaic Solar Energy* for upper-division engineering majors. The one class period module included an in-class lecture and discussion, homework after class, and critical analysis. Assessment included an electronic survey and a homework assignment. Students successfully accomplished the learning objectives and module activities were incorporated into the course content so that students felt this was relevant to their training as integrated engineers.

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