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Critical Consciousness And Engineering Design Teaching Framework

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CRITICAL CONSCIOUSNESS AND ENGINEERING DESIGN TEACHING FRAMEWORK (PRACTICE)

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ABSTRACT

Sustainability in engineering design is not just about the processes and practices established or the materials used and sourced, it is also about the mindset that

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engineers bring to design to carry forth solutions that promote a sustainable world. In this practice paper, we review a teaching framework for an engineering course on design with a contextual perspective. To contextualize engineering design, we incorporate critical consciousness topics to discuss alongside each design process topic. For example, during the unit when we discuss design alternatives in the engineering design process, we also discuss implicit bias and how implicit bias may impact the alternatives that engineers promote in the design. These critical consciousness topics allow for a dialogue that is rooted in history and an understanding of engineering design outside of a vacuum. An adaptation of this course is being taught at two different higher education institutions in the United States. In this paper, we share this teaching framework along with some examples of how we're implementing the framework as well as preliminary results from our study of what impact this work has on students' critical consciousness gains.

1 INTRODUCTION

1.1 Critical Consciousness in Engineering Design

Sustainability in engineering design is not just about the processes and practices established or the materials used and sourced, it is also about the mindset that engineers bring to design to carry forth solutions that promote a sustainable world. Concurrently, there is a lack of focus in engineering design courses on socio-cultural aspects of design, and not only user-driven design. Although more humanistic aspects of the engineering design process have recently been incorporated (Mann, Radcliffe, and Dall'Alba 2007; Zoltowski, Oakes, and Cardella 2012) as it stands, the teaching of engineering design is not focused on the contextual understanding of the social, cultural, economic, and political systems that surround it (Leydens, Lucena, and Nieusma 2014). Nor does it typically cover the gendered and racialized experiences of engineers involved in the design or cases where designs have led to products or industrial processes that are inequitable, oppressive, or unjust (Benjamin 2019; Costanza-Chock 2020; Ozkan and Hira 2021). Here, we differentiate our course from human-centered design courses in that our course does not only highlight the individuals impacted by the design but integrates a critical analysis of how the design enables injustice towards specific individuals and groups of individuals. Moreover, using critical consciousness as the driving concept for our course, we aim to teach design with action at the forefront of our pedagogy. In other words, our course asks students to consider what actions they will plan to take as engineers in light of the knowledge learned.

1.2 Critical Consciousness in Teaching

One of the goals of this course is to provide a contextual perspective to all students about sociocultural and political factors that impact design. In some cases, especially for minoritized engineering students, such a perspective may validate the experiences and knowledge they bring with them to their institution in the pursuit of their engineering career. While not all students may have the language to describe their oppressive experiences, they might have had to develop strategies to manage these experiences. For example, McGee and Martin (2011) discuss how Black students in science and engineering use their understanding of racism in order to manage stereotype threat and its negative effects. By using critical consciousness in the design curriculum, we hope to increase students' understanding of social injustices as they relate to engineering and as they relate to their personal journeys of engineering education.

1.3 Institutional Context

There are two 4-year, higher education institutions in the United States involved in this project. Both institutions are categorized as research-intensive and have the Hispanic Serving Institution designation granted by the Department of Education.

One of the institutions, City University (pseudonym), located in the U.S. Midwest, is urban, non-residential, and serves a large number of low-income students. The College of Engineering at this institution is a mid-size college with ~4200 undergraduate students enrolled. Almost half of the undergraduate students are transfer students from community colleges. The student body in the College of Engineering during the Fall of 2020 semester was 23% female, 22% first-generation, 24% Latina/o, Hispanic students, 5% African American, 25% Asian American. About half of all engineering undergraduate students are transfer students. With regard to

engineering design, all departments in the College of Engineering at City University offer a senior design capstone course. There is variation in how the senior design capstone courses are taught across departments in the college. In some departments, students work with private industry while in others they work with faculty or other campus entities. While capstone engineering design is instituted in the College of Engineering, mid-year (or early years) engineering design is not.

The second institution, Metropolis University (pseudonym), is located in a city in the U.S. Southwest, one of the largest metropolitan areas in the United States. More than 69% of Metropolis University's 30,674 students are from historically marginalized groups, of which 53% are Latinos/as/xs. Nearly half of undergraduates (45%), will be the first in their family to earn a bachelor's degree. Transfer students comprise about 38% of the undergraduate population. Similar to City University, Metropolis University's College of Engineering also offers a senior capstone design course for all engineering and architecture majors. Although some students incorporate social, economic, or environmental aspects into their designs, these are not typically at the forefront nor are these requirements that should be integrated into their projects. There are no engineering design courses in the mid-years or opportunities to do design projects that incorporate social, political, economic, or environmental components into the design process.

2 METHODOLOGY

2.1 Teaching Framework

One of the goals of this project is to develop a teaching framework that incorporates critical consciousness in design. To do this, we also added intergroup dialogue as a component of our framework. "Intergroup dialogue work is a process designed to involve individuals and groups in an exploration of societal issues about which views differ, often to the extent that polarization and conflict occur" (Dessel, Rogge, & Garlington, 2006, p. 304). "Intergroup dialogue is public process designed to involve individuals and groups in an exploration of societal issues such as politics, racism, religion, and culture that are often flashpoints for polarization and social conflict" (Dessel, Rogge, & Garlington, 2006, p. 303). It can provide a safe space to share or express issues related to injustice meanwhile harboring a space where fruitful discussion about injustice can be had across groups. Intergroup dialogue can be used as a mechanism through which engineering students can engage with individuals to advance advocacy, justice, and social change. Some characteristics of intergroup dialogue involve fostering an environment that allows participants to share their experiences, establish communication relationships, facilitate dialogue, and encourage collaborations between participants. Intergroup dialogue is designed to provide a safe and structured opportunity to explore issues that can be sometimes polarizing. Various techniques and strategies (Nagda 2006; Zúñiga and Nagda 2001) fare employed to ensure that a safe space can be established in the classroom to allow for intergroup dialogue.

The working teaching framework is illustrated in Figure 1. This framework is currently being improved, with continued improvements through 2025. The teaching

framework includes three core components: critical consciousness (CC), engineering design, and intergroup dialogue (IGD).

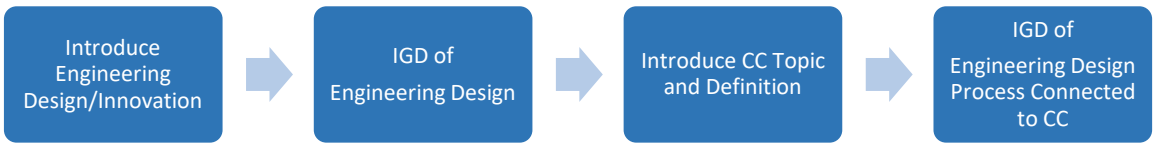

Fig. 1 Teaching Framework

Critical consciousness is used both as a guiding concept to frame the course material and also as a way to inform topics that are included in the course. The focus on raising critical consciousness enabled us to choose aligned topics that would promote cognitive dissonance, discussion, and liberation. It is important to note that the selected topics have been reported in the enginering education literature as topics that often contribute to the normalization of Western-based, Eurocentric values that may perpetuate ideals of disengagement in engineering (Cech 2014). Some of these topics are shown and described in Table 1.

Table 1. List of Representative Critical Consciousness Topics That Guided our Teaching Framework

Critical Consciousness Topic	Description
Militarism	The history of engineering as rooted in military efforts and the contemporary influence of military-driven goals for engineering, as discussed in (Riley 2008)
Globalization	The global-level analysis of impact of engineering design and systems.
Technocracy and techno-determinism	The prioritization and influence of technology on society and individual values as well as on the field of engineering.
Color evasiveness	Originally coined as « color blindness » by (Bonilla-Silva 2017) and operationalized as ignoring experiences or differences based on race, ethnicity, or skin color.
Representation	The need for representation of all people in the field of engineering, specifically in engineering design.
Decolonization	An analysis of engineering as a field that can be understood from non-dominant ideologies.

The engineering design process was taught throughout the semester in a linear-like manner, although iteration and feedback were reinforced throughout. The major aspects of the engineering design process were broken up by teaching unit, and

these included: problem scoping, requirements, design alternatives, testing, prototyping, and iteration.

Finally, intergroup dialogue was used as a tool to promote discussion and reflection in each class around the critical consciousness and design topics presented. As a result, intergroup dialogue is weaved into the whole course and purposefully made visible to the students throughout the semester.

2.2 Implementation

This teaching framework was implemented in two courses, one at each institution involved in this project. The courses at both institutions were taught by a singular faculty member and ran for the duration of a 15-week semester. At City University, a 2-credit hour course in the Department of Electrical and Computer Engineering was offered in Spring 2023. This mid-year course was designed for sophomores (equivalent to a traditional second year in college) and juniors (equivalent to a traditional third year in college) majoring in Electrical Engineering, Computer Engineering, or Engineering Physics. There were 16 students enrolled in the course in Spring 2023. The class met once a week for 2 hours. As part of the course, students worked with a community organization from a neighborhood in the vicinity of the university. At Metropolis University, a 3-credit hour course housed within the College of Engineering was offered in Spring 2023. The class meets twice a week for 75 minutes. This course was designed for first-year College of Engineering students and was open to all science, technology, engineering, and mathematics (STEM) majors although the highest number of students came from the College of Engineering. There were 40 students enrolled in the course, which sought to explore the impact of modern technologies on society. It is important to note that a central aspect of the course was the teaching of fundamentals of engineering design, which was also used as a segway to explore the roles of engineers in decision-making processes. Finally, we should note that at both institutions, the course was advertised as a design course taught alongside a contextual perspective.

In general and across both institutions, the flow of each unit followed in Figure 1, wherein an engineering innovation was introduced via the use of videos, readings, or graphics. The engineering innovations discussed were picked by the instructors to elicit conversations around the design and critical consciousness topics taught in each respective unit. These innovations, when relevant, were also contextualized during the discussion and often problematized to allow for a rich discussion and reflection of the intersection of design and critical consciousness. Some examples of these innovations included: cobalt mining for lithium battery design, the accuracy of facial recognition software, and exclusionary user interface design in gaming controllers. While these examples were gathered from various resources across time and disciplines, a significant number of these examples and their impact on society can be found in works by Benjamin (2019) and Costanza-Chock (2020).

2.3 Assessment

The work presented in this paper is part of a larger project; thus, in this paper, we focus on the assessment of the teaching framework. The assessment of the teaching framework was primarily informed by student reflections, instructor reflections, and student interviews, all of which have IRB approval at our respective institutions. Currently, we share preliminary results on student and instructor reflections.

As part of the course, students were asked to complete ~weekly reflections to answer the following questions: 1) What were some of the arguments, discussions, or facts that interested you the most/least this week? Why? 2) What could an engineer do to implement any of the concepts/topics learned this week to engage in better design practices? 3) How is your understanding of critical consciousness changed, if at all, after this week's class? Remember, critical consciousness is the way in which you perceive the world around you (e.g., engineering and technologies, communities, behaviors, etc.) and the possibilities of taking action to challenge the dominant structures that create the world that surrounds you. The student reflections were collected using Qualtrics and analyzed using MAXQDA and NVivo.

Similarly, every week, instructors were asked to complete a reflection addressing the following questions: What went well? Reflect on teaching, and reaction to material with respect to critical consciousness, learning outcomes, IGD activities. What did not go as planned/as well? Reflect on concerns of implementation of teaching, learning outcomes, reaction to material with respect to critical consciousness, IGD activities. These reflections were done in a Word document and analyzed using MAXQDA and NVivo.

Finally, students were invited for a post-interview with a researcher (not the course instructor) in each respective institution. The interview protocol covers a few topics, but relevant to this paper, the interview protocol includes questions about the impact of the course on the student's critical consciousness. While student interviews are finalized, analysis of these interviews is ongoing and will be shared in a future manuscript.

3 PRELIMINARY RESULTS

3.1 Student Reflections

The students were prompted to reflect on their identities as engineers during the lectures and activities, which proved to be sometimes challenging for the students. They were asked to envision their professional life as engineers and members of society and grappled with questions about the future role they would play as decision-makers. The reflective process provided by Intergroup Dialogue and related activities was profound and allowed them to think about the social, political, and cultural aspects of engineering, as well as the economic, environmental, and historical implications of engineering work. Furthermore, they were encouraged to question issues of power and put their critical literacy skills into practice as they deconstructed the reading materials provided to them.

Most of the student reflections indicated that they appreciated having the space to talk about these issues since these are topics that are rarely discussed in engineering courses. In addition, students discussed the complexity of approaching and solving engineering problems, which was one of the goals of the course – to show students that engineering is interconnected with different systems of power and oppression that create the complexity in which we live. Some students also had conflicting perceptions about social justice and engineering. For example, some students indicated that ethics and social justice were difficult to distinguish concepts because other engineering courses often talked about ethics but not about social justice. Students viewed social justice as a minor aspect of ethical responsibility in engineering, and sometimes completely unrelated to the field. By utilizing intergroup dialogue, students were given the opportunity to reflect on their stance and shift from a culture of disengagement to a more insightful and holistic understanding of their environment. Through this continuous process, students were able to contemplate how engineering design could be approached from a different viewpoint.

3.2 Instructor Reflections

Analysis of instructor reflections is undergoing; however, our preliminary results point to the benefits and difficulties of embedding critical consciousness into a design course. The reflections provide a sense of the collaborative work across institutions to maintain a flow of the class that allows for design activities that are grounded in critical consciousness. From the instructor's perspective, the course allowed students to have class time to openly discuss the topics in Table 1 – such dialogue was reinforced by community guidelines set early on in the class. One of the challenges in the course was that each unit was covered briefly (most done in 1 week and a couple in 2 weeks); thus, students may have felt rushed in reflecting on some topics such as capitalism – that required more background or inter-disciplinary knowledge (e.g., economics, politics).

4 SUMMARY AND ACKNOWLEDGMENTS

The aim of the course was to provide engineering students with the opportunity to expand their thinking by reflecting on a variety of issues that are important to address as critically conscious engineers. By incorporating critical consciousness and intergroup dialogue in the teaching framework of the design course, we sought to promote a different approach to the training of future engineers by creating classroom space for difficult conversations that involve engineering. It is necessary to help students comprehend not just the work of engineers as isolated subjects from society but also the social environment they are operating in. A critical consciousness teaching approach entails using critical pedagogies to break down the complexities of the engineering profession.

The use of critical pedagogies can aid engineering faculty in promoting higher levels of critical consciousness among their students. Although the engineering curriculum has not explicitly aimed for critical consciousness as an educational outcome, it is

possible to investigate how it can be fostered through engineering courses following similar teaching frameworks.

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