2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39971

(WIP): Students' Adoption of Critical Social Theories in Team-Based Engineering Design Projects

Dr. Trevion S. Henderson, Tufts University

Trevion Henderson is Assistant Professor of Mechanical Engineering and STEM Education at Tufts University. He earned his Ph.D. in Higher Education at the University of Michigan.

David Zabner, Tufts University

(WIP) Students' Adoption of Critical Social Theories in Team-Based Engineering Design Projects

Introduction

While engineering has traditionally been regarded as an objective and politically neutral discipline, scholars have recently called for reforms to engineering education that challenge technical/social dualism by integrating the "social realm" into dominant ways of thinking, knowing, and in doing engineering [1-2]. By social realm, we mean to evoke the ways engineering shapes, and is shaped by, social, cultural, political, and ethical systems, that inform who gets to participate in engineering, how and why engineering problems are perceived and undertaken, the results of engineering work, and who benefits from the outcomes of engineering work [1,3]. As scholars become increasingly aware of the role engineering plays in social systems, there have been increasing calls for engineering education to center the development of engineering students' sociotechnical thinking, particularly in the context of complex design problem solving [1, 4, 5].

Existing research points to several pedagogical strategies for fostering sociotechnical ways of thinking in engineering students. For example, one approach to catalyzing students' sociotechnical thinking in engineering design education entails employing community-based design projects that position students to think about social issues as they respond to design challenges [4, 6]. Such approaches rely on the authenticity of the design challenge and presuppose that the authenticity, as manifested in interactions with community members and the construction of personally relevant artifacts, will foster students' sociotechnical thinking [4, 6, 7]. However, other scholars have critiqued this form of community-based learning, often dubbed "service learning," for being extractive, exploitative, or otherwise harmful to the communities in which the design work and other learning activities takes place [3, 8]. These studies suggest that simply asking students to participate in community-based engineering design is insufficient for developing socially engaged engineers. Rather, centering social justice, as well as fostering students' ability to analyze social systems, are key learning activities for catalyzing students' sociotechnical thinking. As a result, teaching students frameworks for analyzing contextual factors (e.g., social, political, economic contexts) as part of the design process is of high importance, particularly as engineering education moves toward more purposeful engagement in fostering students' sociotechnical thinking in engineering design projects.

This paper reports on our preliminary analysis of students' learning in a course, titled Inventive Design, designed to teach both design frameworks (e.g., traditional design models, socially engaged design, human-centered design, design justice), as well as critical social theories (CSTs) (e.g., critical race theory, feminist theories, (dis)ability studies) for analyzing social context and designing to address specific social, cultural, political, and ethical elements of community-based design projects. Our goal was to implement a pedagogical strategy for teaching students CSTs while studying whether students adopted CSTs in their community-based design projects. This ongoing project seeks to answer the following research questions: (a) To what degree do engineering students consider social issues, such as race, gender, and (dis)ability, in their initial ways of thinking in the context of design problem solving? and (b) To what degree do engineering students adopt CSTs in their design thinking following their learning experiences in our Inventive Design course? We focus on the second research question herein.

Methods

The setting for this research study was two sections of an elective design course — Inventive Design — at a small, private university in the United States. Inventive Design was designed to educate students about design frameworks, including traditional prescriptive models of design [e.g., 9-10] as well as emergent alternative frameworks, such as socially engaged design [11] human centered design [12-13], design justice [3], and others. Teams of up to 5 senior-undergraduate or graduate students then responded to one of four design challenges in a semester-long design project.

Educational activities in Inventive Design occurred across three units. In the first unit, students examined, discussed, and reviewed traditional approaches to engineering design, ways of knowing in engineering, and people and ideas traditionally excluded from dominant notions of what constitutes "real engineering work" [14]. In the second unit, students began studying CSTs (e.g., TribalCrit, LatCrit, Feminist Theory, Disability Studies), and discussing ways that concepts from these CSTs might inform their design thinking. Finally, in the third unit, students discussed additional frameworks for product development, such as lean and agile methodologies.

While the two sections—Section A and Section B—contained considerable overlap in their content, and the two instructors communicated about class activities, content, and assignments, the two sections differed in how content was delivered. For example, students in section A studied CSTs over the course of three weeks, including one week on Critical Race Theory, one week on gender and sexuality, and one week on (dis)ability in design. Conversely, students in Section B studied all three topics in one week.

Data Collection

This work-in-progress paper reports on data from three sources: (a) pre-test survey data, (b) observations of student design teams, and (c) students' written and oral assignments in Inventive Design. At the start of the term, we administered the instrument developed by Leydens and colleagues [5] for examining changes in students' sociotechnical thinking. While the survey consists of three sections, we drew only on the first two sections, electing to adopt our own approach to collecting demographic information. In the first section, the survey asks students about their perceptions of engineering practices, such as how important they believe specific skills (e.g., solving technical problems, identifying project-relevant sociocultural issues) will be in their future engineering work. In the second section, the survey asks students about their beliefs about sociotechnical aspects of engineering based on their prior experiences [5].

Second, students were assigned a semester-long project to complete. Each team met with the instructional team to discuss their interests and preferences for semester projects, choosing from one of four project prompts developed by the course instructional teams. The four projects included (a) a design abroad project working with community members in Cartagena, Colombia, (b) a treehouse design project, (c) an educational museum exhibit project, or (d) an assistive technology project for aging citizens. Importantly, while some project prompts specified a geographic context (e.g., Cartagena), others were left broad such that project teams were tasked with making choices and analyzing the ways their choices shaped their design thinking. We posited that positioning students in different contexts might call on different intellectual resources, causing students to make different choices, employ different design frameworks, draw on different CSTs, and address different social issues.

Over the course of the term, a member of the study team observed and documented class activities, including students' discussions about their design projects, in ethnographic field notes. Specifically, the study team member kept jottings in an adapted version of the Classroom Observation Protocol for Engineering Design (COPED) [15]. We adapted the COPED to ask researchers about moments in which students discussed various design frameworks or CSTs in their design discussions. Following class sessions, the study team members transcribed jottings into complete fieldnotes for analysis purposes.

Finally, as students completed their course projects, they were assigned a set of written and oral tasks documenting their work. For example, students were asked to submit a Preliminary Design Review (PDR) where they discussed the context of their design projects, as well as any preliminary ideas and open issues they were considering in their design thinking. Students were also asked to submit final design proposals, which documented their ideation and idea selection processes, implementation details, and other details of their design processes. Finally, students presented final pitch presentations at the end of the term, outlining their design thinking, decisions, and final prototypes.

Preliminary Data Analysis and Findings

Since our analysis of these data is ongoing, this work-in-progress paper reports on preliminary review of survey data from both sections of Inventive Design, as well as written assignments and observations from Section A of the course. Findings from our preliminary analysis of beginning-of-term survey data indicated that most students acknowledged that identifying project-relevant sociocultural issues would be important for their future engineering work due, in part, to the profound impact science and engineering work can have on the public. Still, most students also acknowledged that addressing social aspects of engineering work is not habitual for practicing engineers, with just 10 percent of the sample indicating that they believed practicing engineers consider social issues daily in their work. This underscores the need to educate engineering students on sociotechnical ways of thinking in engineering design courses.

Our ongoing analysis of students' written and oral work indicated that while all teams in the study drew on alternative design frameworks, just 2 of the 5 teams in the study made explicit references to CSTs when describing their design processes. Specifically, teams noted that they drew on CSTs during the information gathering, ideation of key design concepts, and evaluation processes. For example, one team working on the museum exhibit design challenge described how LatCrit shaped their components of their design concepts, noting that LatCrit "considers [the] intersection with other forms of subordination (class, race, gender, language, immigration status)," and argued that "we think language is important to consider, so we have decided to include translations of the 6 most common languages in Massachusetts (Spanish, Portuguese, Chinese, Haitian, French, and Vietnamese)."

Similarly, one team working on the Cartagena project noted how reading from ``the Crits" led them to rethink their information gathering procedures, noting that "traditional knowledge-gathering protocols are not always the best way to gather information about the lives of people from other cultures and backgrounds."

> From Brayboy's Toward a Tribal Critical Race Theory in Education ``Stories are not separate from theory; they make up theory and are, therefore, real and legitimate sources

> of data and ways of being." This key framework is important for our team when researching the experiences and current issues that Nativos face on Isla Barú.

These comments foster confidence that students saw connections between CSTs and their design thinking, decision making, and outcomes.

Scaffolding Contextual Information

One factor informing students' adoption of alternative design frameworks and CSTs appears to be the degree to which the instructional team scaffolds contextual information in their respective projects. While some teams worked in specified geographic, political, social, and economic contexts, other teams chose their design contexts in ways that had implications for their approaches to their respective design projects and thus had implications for their individual and collective learning outcomes. For example, one team addressing the tree house design challenge elected to select one specific family with an autistic child as their user and, as a result, selected a human-centered design approach that they argued focused their attention on the needs of a specific users. Conversely, the other tree house design team chose a community in North Carolina and, as such, developed a process based on socially engaged design, positing that such an approach centered community whether than individual needs.

While contextual information was left ambiguous for the tree house, offering students the opportunity to make assumptions about their design context, the contextual information was explicit for teams working in Cartagena, Colombia. As a result, students drew on CSTs due to their understanding of the specific contextual information influencing the design process. For example, one team wrote about how their understanding of the history of Isla Barú in Cartagena led them to draw on CSTs during their design process:

> Due to the history of Isla Barú, our team took a close reading into TribalCrit, particularly concepts surrounding colonization and autonomy. We also focused on BlackCrit and LatCrit, due to the geography and history of slavery in Cartagena. Some of our main takeaways from these critical theories revolve around how we approached our design process before learning about critical race theories and design perspectives.

Whereas design projects that allowed students to make contextual choices appeared to foster engagement with various frameworks (e.g., socially engaged vs. human centered design), projects that specified contextual information appeared to foster students' adoption of CSTs for analyzing the design context. This raises the question of whether engineering design instructors should specify contextual information for students during the design process. On one hand, the lack of contextual information allowed students the freedom to make assumptions, as well as examine their assumption during the design process. Conversely, the specificity of the Cartagena project pointed students' attention to specific contextual information, which appeared to invite the adoption of specific CSTs. As Jonassen [16] notes, one assumption of all instructional course design is that different learning activities elicit different skills and, as a result, foster different learning outcomes. We argue instructors should make decisions about the nature of contextual information with an eye towards the types of learning outcomes desired in their courses.

On the Nature of Authenticity

Existing research suggests that problem-based learning that resembles authentic, real-world engineering work fosters important learning outcomes [16]. However, these studies most often point to the ways design projects resemble work in engineering industry. In this work, student access to real people and communities appeared to support their adoption of CSTs. When discussing the limitations of their design processes, students often discussed a desire to have greater access to the community their project was meant to serve, whether real or imagined, including a desire to visit the community in-person, interact and design with community members, and draw on community knowledge during the design process. For example, one team that did not discuss CSTs in their work wrote of their experiences designing a solution for the community in Cartagena:

> ...our design was specifically intended for the Nativos, and our design process was centered around design with, not for the Nativos. We were able to approach the completion of this goal with the resources available to us, however we never actually spoke with a member of the community. For this reason, we were unable to truly design a solution with the Nativos and therefore failed to fully achieve this idea of socially engaged design.

Other teams similarly noted how their inability to visit their proposed community, interact with community members, and design with intended users limited their ability to engage social and cultural issues. For example, a tree house design team shared:

> Due to our inaccessibility to the Marion, NC community, we could not directly interact with the community. Thus, we had to learn about the community through demographic, geographic, and governmental information...Lastly, due to time limitations, we were unable to fully understand the social, cultural, economic, political, and environmental contextual factors in Marion, NC.

This pattern suggests that one key to realizing the potential for CSTs to reshape how engineering students engage in the design process is engaging real people, real communities, in real projects. Thus, while it is common practice for engineering programs to collaborate with industry partners to deliver project-based learning experiences that remember workplace problems [16], engineering educators who wish to catalyze students' sociotechnical thinking should include engagement with real people in real communities as a dimension of authenticity in their courses.

Conclusions and Future Work

We contend that teaching students CSTs in engineering design education holds promise for catalyzing students' sociotechnical thinking skills in engineering. However, our work suggests that carefully scaffolding contextual information in course projects, guiding students on avenues for applying CSTs, and developing authentic design project that engage real people in real communities might be important pedagogical strategies for fostering students' adoption of CSTs.

Our future work will continue to expand on the pedagogical framework we designed for this study by developing educational activities designed to position students to draw on CSTs across the design process. For example, we plan to cultivate local, national, and international partnerships to develop course projects that allow students to engage with real communities and apply CSTs to real design projects. Our goal is to address engineering education's technocentrism by educating students on frameworks for analyzing social context in engineering design.

References

[1] Cech, E. (2012). Great problems of grand challenges: Problematizing engineering's understandings of its role in society. *International Journal of Engineering, Social Justice, and Peace*, *1*(2), 85-94.

[2] Claussen, S., Tsai, J., Boll, A., Blacklock, J., & Johnson, K. (2019, January). Pain and gain: Barriers and opportunities for integrating sociotechnical thinking into diverse engineering courses. In *Proceedings of the 2019 ASEE Annual Conference and Exposition*, Tampa, FL.

[3] Costanza-Chock, S. (2020). *Design justice: Community-led practices to build the worlds we need.* The MIT Press.

[4] Leydens, J. A., & Lucena, J. C. (2014). Social justice: A missing, unelaborated dimension in humanitarian engineering and learning through service. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *9*(2), 1-28.

[5] Leydens, J., Johnson, K., Claussen, S., Blacklock, J., Moskal, B., & Cordova, O. (2018, June). Measuring changes over time in sociotechnical thinking: A survey validation model for sociotechnical habits of mind. In *Proceedings of the 2018 ASEE Annual Conference and Exposition,* Salt Lake City, UT.

[6] Shermadou, A., & Delaine, D. (2022). A systemized literature synthesis of encounters with cultural differences in engineering international service-learning literature. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *17*(1), 1-19.

[7] McGowan, V. C., & Bell, P. (2020). Engineering education as the development of critical sociotechnical literacy. *Science & Education*, *29*(4), 981-1005.

[8] Reynante, B. (2022). Learning to design for social justice in community-engaged engineering. *Journal of Engineering Education*, *111*(2), 338-356.

[9] Dym, C. L. (2013). *Engineering design: A project-based introduction.* John Wiley & Sons.

[10] Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007). *Engineering design: A systematic approach.* Springer London.

[11] Center for Socially Engaged Design. (2020). *Socially engaged design process model*. Retrieved from: https://csed.engin.umich.edu/socially-engaged-design-process-model.

[12] Buchanan, R. (2001). Human dignity and human rights: Thoughts on the principles of human-centered design. *Design Issues*, *17*(3), 35-39.

[13] Walton, R. (2016). Supporting human dignity and human rights: A call to adopt the first principle of human-centered design. *Journal of Technical Writing and Communication*, *46*(4), 402-426.

[14] Leyva, L., Massa, J., & Battey, D. (2016, June). Queering engineering: A critical analysis of the gendered technical/social dualism in engineering and engineering education research. In *Proceedings of the2016 ASEE Annual Conference & Exposition*. New Orleans, LA.

[15] Wheeler, L. B., Navy, S. L., Maeng, J. L., & Whitworth, B. A. (2019). Development and validation of the classroom observation protocol for engineering design (COPED). *Journal of Research in Science Teaching*, *56*(9), 1285-1305.

[16] Jonassen, D. H. (2014). Engineers as problem solvers. In A. Johri & B. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 103 – 118). Cambridge University Press.