Using Design to Understand Diversity and Inclusion within the Context of the Professional Formation of Engineers

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Introduction

Three broad and enduring issues have been identified in the professional formation of engineers: 1) the gap between what students learn in universities and what they practice upon graduation; 2) the limiting perception that engineering is solely technical, math, and theory-oriented; and 3) the lack of diversity (e.g., representation of a wide range of people, thought, and approaches toward engineering) and lack of inclusion (e.g., belonging and incorporating different perspectives, values, and ways of thinking and being in engineering) in many engineering programs. Although these are not new challenges in professional formation, these issues are highly complex, interconnected, and not amenable to simple solution. That is, they are "wicked" problems, which can be best understood and mitigated through design thinking, a human-centered approach based on empathy, ideation, and experimentation [1], as it is a useful perspective for addressing complex and ambiguous issues. Thus, this NSF-funded RFE study utilizes a design thinking approach and research activities to explore foundational understandings of formation and diversity and inclusion in engineering while concurrently addressing three project objectives: 1) To better prepare engineers for today's workforce; 2) To broaden understandings of engineering practice as both social and technical; and 3) To create and sustain more diverse and inclusionary engineering programs.

Although our goal is to eventually study these objectives on a broader disciplinary scale, we began by engaging faculty, students (undergraduate, graduate, and alumni), and staff members within two related, but distinctly different Schools at Purdue University: the School of Electrical and Computer Engineering (ECE) and Weldon School of Biomedical Engineering (BME).

To address the three objectives, we utilized a design thinking approach to develop prototype solutions**.** Consistent with a design thinking approach, we involved key stakeholders from each department including students, faculty, staff, and administrators, in the research and design process to co-create solutions that addressed our three interrelated objectives in their specific department. The research study was guided by the following questions:

RQ1. How might we make engineering more inclusive?
RQ2. How might we better prepare engineering graduates for practice?
RQ3. How might we use design thinking to address complex issues in engineering education?

In this paper, we provide an overview of the multi-year project and discuss emerging findings and key outcomes from across all phases of the project. Specifically, we will showcase how the research has identified the concurrent ways that understandings of diversity and inclusion are impacted significantly by the local contexts (and cultures) of each department while being compounded by the larger College/University/discipline-wide understandings of who is an engineer and what skills legitimize the identity of "an engineer."

Background

A variety of studies have argued that current engineering curricula effectively prepare students for technical and theoretical aspects of engineering as a profession while failing to prepare students for the complex realities of modern workplaces (e.g., complex social environments, teamwork, conflict communication, working in a global workplace) [2]-[5]. This may be because of the singular way that the value and perception of engineering is promoted and reinforced within engineering programs—that is, an explicit focus on engineering as technical and *not* human-centered or inclusive of alternative positionings of what and who constitutes a successful engineer. Despite change in some engineering discipline profiles and curricular reforms for engineering education, the gender and diversity gap in the student demography of most engineering and computer science departments in universities persists [6]. Although it is important to be "Changing the Conversation" [7], we argue the real need is beyond demographic shifts and one of disciplinary disruption and transformation. That is, engineering itself needs to be constituted as both social and technical such that professional preparation, engineers' identities, and diversity and inclusion are seamlessly integrated throughout.

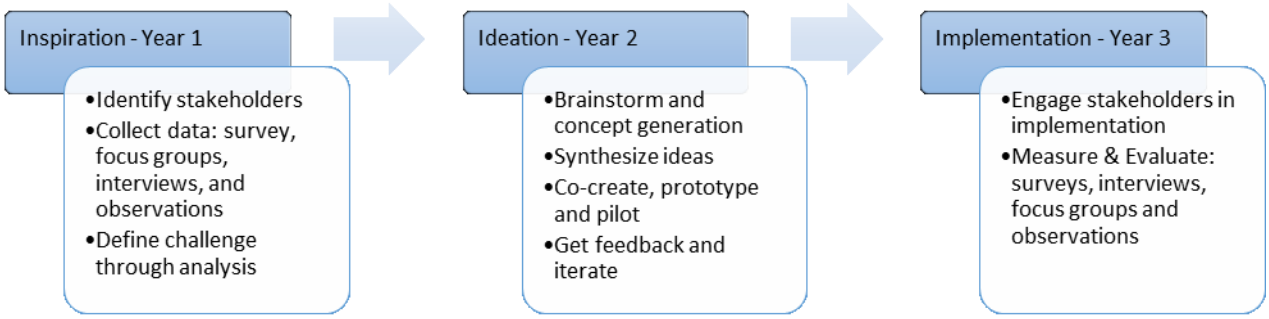
To make progress towards this goal and achieve change, a dual focus on (1) the local contexts of the ECE and BME departments and the (2) disciplinary culture is necessary for two reasons. *First,* it is important because the local contexts and the disciplinary cultures mutually reinforce one another as evidenced through values, assumptions, and types of knowledge that are (re)produced [8]. Second, both local and disciplinary cultures provide glimpses into the current and "real" states of everyday experiences and practice of stakeholders within ECE and BME. Understanding these current cultural states is necessary inasmuch as it provides insights into the changes that are needed to improve cultural states [8]. Taking a culture-centered approach can create opportunities for both sustainable and widespread change efforts--particularly in professional formation contexts and within engineering education. To enact cultural change, it is vital to shed light on/illuminate the hidden assumptions, the taken-for-granted values, beliefs, and norms that govern and guide individuals within a culture [8].

Furthermore, unpacking engineering's core values and assumptions of engineering identity provide an opportunity for engineering educators to create more inclusive environments. Students' experiences of engineering within their undergraduate education shape their understanding of the nature of the work done by engineers, the skills and knowledge that are valued and needed in engineering, and whether these things align with their personal identity and values.

Project Overview

Our project is organized around the three phases of the design process (inspiration, ideation, and implementation), and embedded within the design process is a longitudinal, multiphase, mixed-methods study (Figure 1).

Figure 1. Design Thinking Process adapted from IDEO [9]



A summary of the project data collection by design phase and stakeholder group is given in Table 1. In Year One, we implemented activities of the Inspiration Phase which included collecting and analyzing survey, interview, and observation data from a broad set of stakeholders which included faculty, staff, and administrators and students (undergraduate and graduate) in both ECE and BME departments. During Year Two, the Ideation phase, we facilitated design sessions with faculty, staff, and students from each of the two departments to investigate underlying issues and then to develop prototypes related to diversity and inclusion and professional formation. During the Implementation phase, in Year Three, we worked with BME and ECE stakeholders to further define and develop the prototypes. Additionally, we continued to assess stakeholders' understanding of the effectiveness of design thinking toward organizational change in both departments.

Design Phase	**Students**	**Faculty/Staff/Admin (FSA)**
Inspiration	• Surveys (N=31 BME & 134 ECE) • Interviews (N=12 ECE, N=18 BME) • Observations (N=3 ECE; N=2 in BME)	• Interviews (N=13 ECE, N=16 BME) • Observations
Ideation	• Brainstorming • Co-creation/prototyping sessions for both solution and implementation • Informal and Formal Feedback Sessions	
Implementation (ongoing)	• Interviews (N=20 ECE, N=16 BME, 5 other) • Evaluation of the process • Observations	• Interviews (N=15 ECE, N=15 BME) • Evaluation of the process • Observations

Table 1. Data Collection by Design Phase and Stakeholder Group

Findings

Our research team has conducted several analyses that, together, are providing insight to the disciplinary, department, and university cultures that underlie the interconnected issues related to professional formation, integrated socio-technical understands of engineering, and diversity and inclusion. Furthermore, the analyses are revealing how those cultures can shape the ways in

which design thinking can be used as an effective strategy for addressing these wicked problems of social dynamics and organizational change. In the following sections, we briefly describe the context of these analyses and summarize the findings.

Students' experiences regarding and understanding of diversity and inclusion are impacted by the disciplinary ecosystem of Electrical and Computer Engineering (ECE).

Using a constant-comparative method, we analyzed interviews from 18 current or former ECE students to uncover students' understandings of the disciplinary culture of ECE and to better understand their how diversity and inclusion is experienced within the ECE department. Using the findings from the interviews, observations were conducted with three current ECE students to further understand their experiences in ECE. The findings indicated that the support for diversity and inclusion within the ECE department is often constrained and limited as a result of the prevailing macrosystemic values (e.g., masculine ideals of who and what counts in ECE; see [10]) within the department. These values minimize the importance of not only those diversity and inclusion initiatives in the department, but also those across the university [11].

The disciplinary culture of BME promotes independence and individuality as norms for student success, and students require different forms of capital (e.g., social, cultural, and navigational) to be successful.

This case study examined the culture of the BME department and its underlying assumptions regarding what sources of cultural and social capital undergraduate students need to be successful. Through interviews with 18 current or former BME students, we examined norms of teaching and learning in the BME disciplinary culture, discovering that students perceived the BME culture as reinforcing highly independent strategies for learning and professional development. More specifically, students perceived they were 'on their own' in: (a) developing a specialty in a BME subfield to be marketable upon graduation, (b) learning course content by teaching themselves, and (c) finding and pursuing professional development opportunities. As a result, students drew on resources outside of the program such as family and peer social networks, high school training in STEM subjects, and other forms of social and cultural capital. As under-represented minority (URM) students and first-generation college (FGC) students are less likely to possess these forms of capital [12]-[14], this finding suggests that BME cultures may raise barriers to URM and FGC student [15].

The disciplinary cultures of the ECE and BME departments impact the effectiveness of the design thinking process.

Analysis of the post-design session interviews revealed the impact that the disciplinary and organizational cultures of both ECE and BME impacted (1) the effectiveness of design thinking toward culture change, and (2) the space in which change occurred (e.g., individual versus systemic levels). Reflecting a more limited design culture within the school, the stakeholders in the ECE design sessions recognized and acknowledged limitations in their ability to make large-scale change within ECE. As such, prototypes developed by ECE stakeholders from the design thinking sessions addressed interactional and day-to-day issues that faculty, staff, and students face pertaining to diversity and inclusion. However, because they were issues that the

stakeholders had the power to enact, progress has been made. On the other hand, the stronger design culture of BME (compared with ECE) was reflected by the recognition of both the need and the ability to address large-scale, macro-level diversity and inclusion issues within the school (e.g., defining the organizational identity of BME; redefining recruitment practices and protocols to address different populations that were missing from the BME student population), as well as structural issues at the university level. However, it has also been difficult to see significant changes immediately with regards to these macro-issues identified by the BME stakeholders [16]-[18].

ECE faculty's attitudes and perception of behavior control and norms all impact change related to diversity and inclusion.

Using the model for intention given by Fishbein and Ajzen's theory of reasoned action [19], we analyzed the ECE faculty interviews to identify themes which represent opportunities for, or barriers to, improved diversity and inclusion in the department. The core idea of the reasoned action model is that any behavior is directly predicted by an intention to perform that behavior, and that intention is created through three main factors: attitude, perceived norm, and perceived behavioral control. Within this study, the three factors necessary for intention could be rephrased from faculty's perspective as "I care about this" (attitude), "I should do something about it" (perceived norm), and "I can do something about it" (perceived behavioral control). Without any one of these factors, faculty can justify not taking action; they turn into "It doesn't matter," "It's not my job," or "There's nothing I can do." The interviews revealed that 1) department leadership's visible support was a notable influence on faculty's development of a positive attitude toward diversity and inclusion; 2) faculty deemphasized their roles as teachers because of a perceived norm to prioritize research, which originated from cultural values of the department; and 3) that faculty perceived a lack of behavioral control over diversity and inclusion. The study found that, to see effective, sustainable change, attitude, perceived norm and perceived behavioral control must be addressed together, and failure to do so could not only be ineffective but contribute to more negative attitudes towards diversity and inclusion [20].

Conclusions and future work

Our research has identified ways in which student and faculty understandings of diversity and inclusion are impacted significantly by the local contexts of their school and compounded by the larger college, university, and discipline-wide understanding of who is an engineer and what skills legitimize the identity of "an engineer." Currently, we are developing strategies for using design thinking in social change research that could be implemented by other academic programs to address complex issues in their departments. In addition, we have initiated a new phase of post-study interviews of engineering students and faculty members. In this phase, students and faculty are being interviewed and analyzed to understand the impact of this NSF project.

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