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WIP: Integration of Inclusive Mindset in a Middle-Year Biomedical Engineering Course: a Study Over Healthcare Disparities via Story-Driven Learning

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Abstract

There is a recognized need for increased diversity and inclusion in engineering education and in the engineering workforce. One approach to address this need is to provide students with frequent learning opportunities to practice adopting an inclusive mindset in their interpersonal interactions as well as in their engineering analytical problem-solving and design practices. This manuscript illustrates how we are infusing these learning activities in our major-required analytically focused courses. We describe a work in progress intervention in a major-required second-year analytically-focused biomedical engineering course called "Conservation Principles in Biomedical Engineering". This course is taught using the problem-solving studio (PSS) approach, developed by our department in 2008, which is a highly interactive apprenticeship learning environment in which students work in a stable team of four for the entire semester. In this intervention, students are challenged to consider bias in engineering design and its impacts on others through a semester-long project composed of a series of individual and team exercises. This intervention is designed to raise students' awareness of bias in biomedical engineering designs and processes and the impacts they have on them and on others.

Demand for inclusive design and responsible innovation

Engineers' works significantly affect the world, so they should be aware of assumptions they make when they create a new product. It means that consideration of inclusive values in their assumptions scaffolds the engineering ethics (Feister *et al.*, 2016; Dyrud, 2017). Just within subfield of biomedical engineering, unaddressed biases have led to situations such as not including women's anatomy and physiology in the design of joint implants resulting in irreversible health issues, given the fact that women form more than 65% of joint replacement patients makes this issue even more painful (Hutchison, 2019), pulse-oximeters read the SpO_2 level of patients with darker skins 8% lower than real value, which can have some fatal consequences for the patients especially at the time of coivd-19 pandemic (Sjoding *et al.*, 2020), left-handed surgeons not receiving appropriate equipment during training (Adusumilli *et al.*, 2004), and facial recognition systems not registering the pain expressions of dementia patients (Taati *et al.*, 2019).

Lack of attention to middle-years course interventions

In our previous work (Nezafati, Chua and LeDoux, 2020) we mentioned the idea of creating value for the end-users and consideration of their demands are normally the focus of introductory design-based courses (Gunnarsson, Birch and Hendricks, 2019), or culminating senior capstone experiences or senior projects (Cezeaux *et al.*, 2008; Nasir, Kleinke and McClelland, 2016). Given the fact that, traditionally the main focus of middle-years courses are on technical content and analytical procedure (Lord and Chen, 2014), the demand for attention to "middle-years" courses will be more vivid. Although, there has been some efforts to propose a list of potential hypothetical modifications which incorporate universal designs (Burgstahler, 2015) for product development into middle-years undergraduate courses to consider disabled people needs in the designs (Blaser, Steele and Burgstahler, 2015), but still the bulk of literature is focused on introductory design-based courses or senior projects. Without explicitly developing inclusion skills in the context of analytical and technical practices, students might consider including diverse users and teammates only in specific contexts. How might instructors integrate inclusive practices into these courses without adding even more material into content-packed classes? This work in progress paper presents an ongoing case study as one attempt to answer that question.

Intervention to identify intrinsic motivations for improving a non-inclusive design

Table 1: Frame work of inclusive design analysis intervention

Learning objective	The Hook	Problem Finding	Value Creation
Cognitive:	Introduce the problem of non-inclusive designs	Find and critique of existing design	Analyze and propose a more inclusive design
Affective:	Story 1: Personal experience	Story 2: Harm to a specific person	Story 3: Good done for a specific person

The project begins by challenging students to work on their own to look for examples of biased/flawed biomedical engineering designs. Also, they are asked to share a story of a non-inclusive design that has personally affected them or a loved one. By having students tell a personal story we hope to make the impact of bias in engineering design seem more real to them, and to increase their intrinsic motivation and sense of connection to the project.

Next students share their stories with their teammates. Together they discuss the importance and impact of each design shared by their teammates, both on a personal and societal level. They identifying a flawed/biased engineering design they'd like to learn more about. Then create a case study designed to inform and motivate members of the lay public. After creation of the case study, students are asked to write a second story, to illustrate, in an emotionally evocative and concrete way, how the flawed design has negatively impacted an individual or group of people. The second story could be about a real case or a creative story about a hypothetical person.

In the last part of the intervention each team expand their work and propose recommendations for pursuing future designs and/or research efforts that will help create value for people who are not currently positively impacted, or perhaps are even negatively impacted, by the current design. Also, students write third story for a professional audience indicating the positive transformation the user would have if they receive the modifications the proposed. The story should be able to motivate the audience to invest resources into creating and implementing the new design that will create value for the previously disenfranchised group. It should help the listener see and emotionally feel the impact that the new design will have on others.

Preliminary results and discussion

In the first attempt of this project in fall 2020, our students (121 students in 3 sections of the class) were asked to find three cases of non-inclusive designs. As a result, they found 86 independent cases of non-inclusive designs in medical science and biomedical engineering. They also were asked to categorize the cases by the affected demography and the specific subfield of medicine. Figure 1A, shows the affected demographics. The gender and racial biases with combined total of 69 %, had the highest number of cases our students found. Bias against different age groups, people with pre-existing conditions, different BMIs and body sizes, and socioeconomical status were the other demographics that were affected by these cases of bias. As it can be seen in figure 1B pharmaceutical industries with 37% of the cases have significantly the highest number of cases. Orthopedics industries, health monitoring, health software, cardiology, and women health were the following categories of medical science which they found cases in them. Given the fact that the students were able to identify this large number of cases in a short period of time, indicates a large demand for developing a frame work for responsible design. The demand for such a framework was discussed in other fields of engineering such as geoengineering (Owen *et al.*, 2013), and in this work we are describing our effort to have a few initial steps in the field of biomedical engineering and medical science.

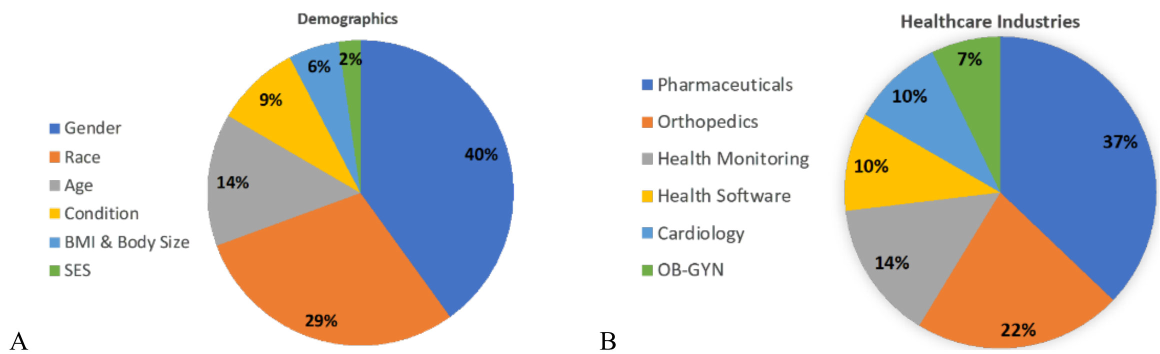

Figure 1: A. the distribution of demographics affected by cases of non-inclusive designs found by our students. B. the distribution of cases we found in the medical subfields.

Non-inclusive designs could result in discrimination when the engineers do not consider the outcome-relevant information, instead incorporate irrelevant demographic assumptions. There are two main factors that can escalate this discrimination: noise (number of errors made in the decision making) and bias (the degree to which errors disproportionately favor one group over another) (Axt and Lai, 2019). In this intervention our students focus on the bias in designs and not the existing noise. In all the cases that our students were able to find errors in assumptions took place in a way that put one demographic group in disadvantage. So, they proposed solutions to reduce the errors that can favor one group over the other groups.

During our preliminary analysis we observed that establishment of empathy for the affected person by bias can potentially work as the intrinsic motivation (Ryan and Deci, 2000) to solve the problem of the flawed designs. After cross referencing the stories with the topic of case studies and proposals the groups created, we noticed 34% of the groups (11 out of 32) were motivated based on the empathy they have formed for a person they know. This conclusion was drawn from the fall 2020 cohort. We are expecting to reach more conclusive results by extending our analysis and data collection.

Our expectation is that students who complete this project will learn that many engineering analyses and designs are flawed in the sense that they do not consider the needs of all people, resulting in designs that benefit some but not others. They will better understand how biases can lead to flawed designs that adversely impact people's lives. We expect that this increased awareness by sharing personal stories and the stories of a person who was affected by the will motivate them to find ways to minimize the impact of their personal biases on their engineering design work by, for example, working with teams of people who differ from themselves in terms of their life experiences, perspectives, and skills. Ultimately, we hope that students will leave with a greater appreciation for how to use their engineering skills to create value for others.

Future work

After initial assessment of the data we collected during fall semester, we noticed some room for improvement, both in design of the intervention and data analysis. Currently we are working on the data, to find a correlation between, personal motivation and the artifacts our students create. Also, we want to evaluate the effect of external factors such as society, school and the events happening nationally or globally, on students' motivations to work on their proposals. A follow up study will evaluate the effect of doing such a project on motivation of students, after specific period of times (following semester, a year after and after graduation).

Appendix:

An appendix was created in engineeringunleashed.com platform, which includes the detailed instruction for the faculties who want to incorporate this intervention in their classroom. In this appendix we have included: handout for students, the showcase of representative students works and some useful references to help both students and faculties to understand the mindset behind this project.

https://engineeringunleashed.com/card/2479

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