



Exploring the Interplay of Diversity and Ethics in an Introductory Bioengineering Course (Work In Progress)

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Introduction

Ethics and diversity are critical components of engineering training and practice, but most undergraduate engineering programs do not address these issues in-depth [1-3]. In this work-in-progress, we describe the design and implementation of a novel curriculum that allows early engineering students to explore the interplay of diversity and ethics in an engineering context. Importantly, our curriculum can be incorporated into any engineering course, and thus serves as a model for educators in any engineering discipline.

This work-in-progress describes student response to three rounds of pilot efforts [4] and how we are developing and implementing the first full offering of our curriculum through a new honors section of a large introductory bioengineering course.

The introductory course aims to provide broad exposure to several areas of research in bioengineering such as cancer diagnostics, medical device development, regenerative medicine, global health, and synthetic biology. The course emphasizes critical reading of scientific literature and technical writing, and broadly covers the engineering design process, creative problem-solving techniques, engineering ethics, social constraints, and other design principles. Students complete an end-of-course team project where they design a solution to a global health problem of their choice.

Learning Objectives

We aim to engage early engineering students in meaningful discussion about the intersecting roles of diversity and ethics in bioengineering, enabling them to apply course competencies to their future engineering practice. Our learning objectives include:

- 1) Summarize key case studies regarding diversity-related ethics in STEM
- 2) Identify how cultural concepts of race, gender, sexuality and disability have shaped scientific thought (and vice versa) through history
- 3) Critically evaluate literature regarding ethics and diversity in bioengineering
- 4) Analyze how engineers handle implicit bias during research and design processes
- 5) Propose approaches to promote ethics and diversity in engineering practice

Curriculum Design and Innovation

Our curriculum includes topics such as the importance of diversity and ethics competency in engineering; historic and current case studies of diversity-related ethical issues in bioengineering, and how historical perceptions and contexts still influence modern scientific thinking and engineering design; advocacy and representation of minorities in engineering; evidence supporting the value of inclusive teaching and diverse teams; and best practices for advocacy and representation of diverse peoples in engineering.

This curriculum is innovative for several reasons, including its accessibility for early engineering students, ability to reach a large and diverse group of students, and its explicit relationship to engineering. Furthermore, this curriculum may promote engagement of underrepresented

students early in their educational careers, and provides positive messaging about the importance of approaching engineering ethics through the lens of diversity and inclusion of all people.

Although upper-division bioethics or medical anthropology courses may address similar content, our curriculum on the intersection of ethics and diversity is unique because it engages early engineering students in the context of a required introductory course. This is important because upper-division courses are not accessible to first-year bioengineering students. Implementing this curriculum in a required introductory bioengineering course allows us to reach a greater number and diversity of early engineering students, who may not be familiar with or already interested in these topics. In other words, there is no self-selection for enrollment.

Implementation

We purposefully chose to implement this curriculum in a large introductory course for several reasons, including: 1) to provide an accessible opportunity for underrepresented students who are interested in engineering to engage early in their undergraduate careers, as these students are less likely than other early-interest students to eventually attain engineering degrees; 2) to impress upon a broad audience of early engineering students that diversity and ethics are critical topics in engineering and that they should think critically about this throughout their engineering coursework and career; and 3) to underscore the importance of these issues by integrating diversity and ethics into engineering coursework instead of presenting this material as an optional add-on or special topic.

Briefly, we are building this curriculum in three contexts, with the goal of implementing all three simultaneously starting in Autumn 2018.

- 1) Three quarters of pilot rounds where we introduced this material in two class sessions and one assignment in a large introductory bioengineering course taught by the authors (2017-18). These materials are now integrated into the course and beginning in Autumn 2018 will be included in future course offerings.
- 2) First offering of a new honors section of the introductory course for students to delve deeper into topics involving ethics and diversity (Winter 2018).
- 3) Develop an expanded curriculum for a new stand-alone honors course (to be taught in Autumn 2018).

The general format of our curriculum is: lecture to introduce topic, pre-assignment including reading and written reflection, in-class discussion, and post-class reflection. We will share curricular materials such as lectures, assignments, reading lists, and in-class discussion prompts at the conference. Please see the honors course schedule in Appendix A.

Preliminary Assessment

Over three quarters, we have introduced parts of our curriculum in an introductory bioengineering course through the addition of two class sessions and a reflective assignment. In addition, we made an effort throughout the course to explicitly relate ethics and diversity to the existing bioengineering content.

In these three quarters, student feedback from anonymous end-of-quarter surveys was overwhelmingly positive (Table 1). Almost all students indicated that they thought ethics and

diversity were important topics for the course and a valuable use of class time. Many students expressed shock at the abuses of marginalized people in both historical and current cases, and the pervasiveness of subjective bias in the seemingly fact-based fields such as science and engineering.

Table 1. Student comments on initial presentation of diversity and ethics curriculum in large introductory bioengineering course

Comments on strengths:

“I learned that research is only as objective as those who are conducting it”

“I now have a better grasp of ethical issues I should take into account in design and research for the future”

“Before learning about the ethics and diversity in science and bioengineering specifically, I had never considered the effects of these within the field. I think it is extremely interesting how the history of marginalization in society has had such a big impact on science and continues to affect us as a nation.”

“The lessons of diversity and inclusion are particularly relevant to me because I am associated with the historic majority in politics, science, and socioeconomics. Due to this, I feel that it is essential to lead by example for other members of my demographic that may unknowingly have cultural biases. I feel that it is part of my social responsibility due to my demographic to become an ally for underrepresented groups.”

“In the past few weeks, I have learned a great deal about ethics and diversity in the bioengineering community... my understanding of the subject has deepened significantly, and has allowed me to reflect on what I have learned in the past about research in the medical field.”

“I realized that my perspective on engineering solutions was very narrow and biased... it was as if I took a strong blow to the head. Being male, I did not see that the solutions to my problems did not solve the same problem for others with different characteristics.”

“I learned that people are different and in order to benefit the greater public I should always keep an open mind and consider different groups. A sentence from the lecture that resonated with me and I wrote down was ‘If we don’t design for everyone - not everyone benefits from engineering.’”

“These lectures and quiz sections have been my favorite so far in this class. Learning about how extreme the lack of diversity in the STEM field is was stunning to me... I had never considered that social biases could be reflected in science, a topic which I took for cold hard facts.”

Comments on weaknesses and areas for improvement:

Feeling that [university] generally is very biased in one direction can be intimidating. I don’t disagree with a more liberal perspective, but it makes it hard to even discuss other ideas at times.

I actually walked away mildly shocked and offended by their implication that STEM is mysteriously prejudiced against women and minorities.

It would have been nice to have a "positive" spin to the presentation to make note of recent victories for ethics and diversity in STEM.

However, there were a few students who expressed dissatisfaction or resistance to this content. Although this small number of students represented less than 2% of students in three offerings with a total of over 300 students, we did attempt to address these concerns. For example, in the first offering one student commented that we implied “that STEM is mysteriously prejudiced” (Table 1), so in future offerings we provided more data from scientific research and emphasized the legitimacy of the journals where this work was published.

Also in the first offering of this material, one student suggested that we could include “a ‘positive’ spin to the presentation to make note of recent victories for ethics and diversity in STEM” (Table 1). We agreed that we wanted students to feel empowered to do something positive, so in future presentations we included information about campus organizations that support underrepresented groups in STEM such as Society of Women Engineers [5], Society of Black Engineers [6], and Out in STEM [7]. We also urge students to continue learning about ethics and diversity.

Further Exploration of Diversity and Ethics in an Honors Section

The honors students are concurrently enrolled in the introductory bioengineering course; they attend the same class sessions and complete all assignments as their non-honors peers. In addition, the honors students attend a two-hour discussion section once a week and complete additional weekly assignments including weekly readings, written reflections and responses, and a final paper on a topic of their choice related to the role of diversity/diverse identities in engineering practice.

Although the honors section is still in progress, we appreciate the range of topics chosen by the students for their final paper (Table 2) and the personal motivation many of the students have described in class discussions for learning more about diversity and ethics in engineering.

Table 2. Topics identified by students for final paper in honors section
Impacts of science/research on marginalized groups, particularly African-Americans, in the United States.
Exploration of how modern cultural/societal perspectives on disability affect participation of people with disabilities in STEM.
Examination of how various media forms enforce stereotypical roles of women, thus discouraging women from entering STEM fields.
Evaluation of scientific attempts to classify sexual orientation based on neurophysiological findings and analysis of how this research influences our perceptions of gender and sexual identities.
Exploring the ethical ramifications of artificial intelligence and the study of neural networks, particularly focusing on who will benefit/not benefit from this technology and potential negative consequences.
Considering the role of women in computer science over time, particularly examining how computer science went from a female-dominated field to a male- dominated field, with a focus on media portrayal, stereotyping, and institutional barriers.

At the conference, we will share excerpts from honors students' end-of-quarter reflections and other assignments. In addition, we will present instructor observations and end-of-course student evaluation results.

Conclusion and Future Directions

In this work-in-progress we describe the overwhelmingly positive student response to pilot efforts in an introductory bioengineering course and the first implementation of our curriculum in a new honors section focused on the interplay of ethics and diversity in engineering.

In addition to the anonymous written surveys, in the future we will assess the impact of our curriculum by analyzing student reflections and also by examining whether students in the introductory bioengineering course change the content of assignments in response to exposure to our curriculum. For example, this quarter we have noticed that the final projects for the introductory bioengineering course have included design considerations for people with disabilities (e.g. designing a waterless toilet for use in low-resource areas that is accessible) and have emphasized the social justice aspects of design (e.g. creating more equitable workloads between men and women by creating more efficient ways for women to carry water from its source to their homes).

At the conference, we will share curricular materials including lectures, assignments, reading lists, and in-class discussion prompts. In addition, we will provide assessment materials from the Winter 2018 introductory bioengineering course and honors section, including student surveys, excerpts from student assignments, and instructor observations. Finally, we will share how we plan to thoughtfully consider student feedback and our own observations in the honors section this quarter when we design the expanded curriculum for the upper-division course we will launch in Autumn 2018.

Bibliography

1. National Academy of Engineering. (2008) "Changing the Conversation: Messages for Improving Public Understanding of Engineering." The National Academies Press, Washington, D.C
2. Hess, J.L. and Fore, G. (2017) "A Systematic Literature Review of US Engineering Ethics Interventions." Science and Engineering Ethics. DOI: 10.1007/s11948-017-9910-6.
3. Herkert, J.R. (2010) "Engineering ethics education in the USA: Content, pedagogy and curriculum." European Journal of Engineering Education, 25:4, 303-313. DOI: 10.1080/03043790050200340
4. C. Gunnarsson, C. Birch, and D.G. Hendricks. "Exploring the Interplay of Diversity and Ethics in an Introductory Bioengineering Course", Pacific Northwest Section Conference, American Society for Engineering Education, Seattle WA. (April 2017)
5. Society of Women Engineers, <http://societyofwomenengineers.swe.org/>
6. National Society of Black Engineers, <http://www.nsbe.org/home.aspx>
7. Out in STEM, <https://www.ostem.org/about>

Appendix A. Course Schedule for Honors Section Exploring Interplay of Ethics and Diversity in Engineering.

Date	Topic	Assignment Due
1/9	Introduction + Intro to Engineering/Design for Social Justice	Pre-class survey Classroom expectations
1/16	History of Gender/Sex	
1/23	History of Race	Topic proposal due
1/30	History of Disability	Annotated bibliography due
2/6	Designing for Diverse Populations Watch “Fixed” documentary in class	
2/13	Scientific Communication // Universal Design Guest Lecture	First draft due
2/20	Peer Review // Designing Research	Peer review worksheet (I like this... I wish you did this ... what if you did this...); Instructor feedback
2/27	Representation in Engineering	Optional second draft for more instructor feedback//in-person feedback
3/5	Course Wrap-Up and Final Reflection	
3/12	FINALS WEEK	Final draft due Mar. 13 11:59 p.m.
Thank you for a great quarter! ☺		