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”How Engineering Impacts Diversity, Equity, and Inclusion”: A Case Study in Graduate Course Design and Assessment

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Abstract

Racist soap dispensers, algorithmic bias, and the confrontation of historical inequities exemplify incomplete engineering. What these case studies neglect to account for is diversity, equity, and inclusion (DEI). How does the engineer of the twenty-first century understand the impact of their research in the context of DEI? Non-technical engineering courses provide important tools to better understand the sociotechnical systems of the profession. This study evaluates a new graduate level course titled "How Engineering Impacts Diversity, Equity, and Inclusion" that emphasizes the importance of non-technical engineering skills, with a focus on DEI. This course considers writings from a variety of authors, representing distinctive perspectives on matters of diversity, equity, and inclusion. Through active engagement with this material, this course confronts history to identify and understand instances of racism, sexism, discrimination, and bias, specifically in science and engineering. This study builds on previous scholarship presented to ASEE along with other related fields to demonstrate how discussion-based courses challenge graduate students to think more critically about the engineering design process and the active integration of the social dimensions of engineering problems.

Keywords

Science, technology, and society
Diversity, equity, and inclusion
Graduate instruction
Course design

Diversity, Equity, and Inclusion

Diversity, equity, and inclusion (DEI) – what do these three words mean? Though DEI terminology frequently appears as intricate buzzwords, undergraduate and graduate students and instructors rarely discuss the greater understanding of these concepts, particularly in engineering classrooms. An overwhelming number of institutions of higher education in the United States now support different divisions attending to DEI or include explicit language defining the terms in university statements. Common themes emerged through an analysis of five of these institutions: the University of Virginia (UVA), Duke University, Cornell University, Stanford University, and the University of Michigan. These universities typically characterize diversity as the ways in which people differ, including the characteristics such as age, religion, disability, sexual orientation, education, etc. that differentiate one individual from another. Equity is broadly defined as fair treatment, access, opportunity, and advancement for all people. Inclusion involves an active, intentional, and continuing process to build community well-being and belonging. [1] [2] [3] [4] [5] While these definitions exhibit one way of thinking about these important concepts, the definitions alone do not indicate ways in which to turn these thoughts into actions. The translation of these tools into actions can best be understood in the classroom. Contextualization of DEI in relation to the engineering profession is not uniformly integrated, especially within the context of engineering education. The next section briefly introduces the exploration of DEI within the American Society for Engineering Education.

Incorporating Diversity, Equity, and Inclusion in the American Society for Engineering Education

A search through the conference proceedings of the American Society for Engineering Education (ASEE) produces over 1,500 results for the keywords "diversity, equity, and inclusion." A small percentage of these results appears within the regional conferences, while most results appear at the annual conference. Approximately 327 papers with those keywords were presented at the 2022 ASEE annual conference and exposition, compared to 104 at the 2018 ASEE annual conference and exposition. [6] Though these results indicate a clear interest in researching, understanding, and practicing DEI within engineering education, instructors have not yet developed enough clarity about the integration of these themes within the curriculum. Many papers emphasize the terminology, but do not discuss the practice of navigating these ideas with students. The next section contextualizes one approach to implementing DEI in practice at the graduate level.

Understanding Graduate Engineering Education at the University of Virginia

After the deaths of George Floyd, Breonna Taylor, and others, many universities created class offerings and other initiatives that reflected the need for deeper conversations about race. The University of Virginia Department of Mechanical and Aerospace Engineering (MAE) created a Graduate Student Board as part of their DEI-DRIVE (diversity, equity, and inclusion – diversity, respect, inclusion, vision, and equity) initiative. The Board developed a proposal for a course on diversity, equity, and inclusion, complete with the class's structure, learning objectives, and a weekly outline of lesson resources. Though MAE wanted to offer this course, there were no available faculty members in the department able to teach it. The University of Virginia School of Engineering and Applied Science features an embedded program called Science and Technology in Society (STS). Scholars in this department, primarily social scientists, specialize in teaching engineering ethics. The STS program offers courses at the undergraduate level that attend to conversations about DEI, but does not consistently offer many similar courses at the graduate level. The MAE graduate students' proposal therefore created a great opportunity for cross-departmental collaboration.

The field of Science and Technology in Society attends to the nontechnical skills necessary for a well-rounded engineering education. STS draws from a full range of disciplines in the social sciences and humanities to examine how science and technology simultaneously shape and are shaped by society, including politics and culture. The nontechnical approaches offered by STS provide engineering students with conceptual tools to think about engineering problems and solutions in more sophisticated ways. However, no universal standard for incorporating these skills into engineering curricula exists. As Seabrook et al. describe in "Teaching STS to Engineers: A Comparative Study of Embedded STS Programs," a variety of STS distribution methods means that some programs feature standalone courses from outside the engineering school, while others incorporate STS material into more traditional engineering courses. [7] These mixed approaches indicate the scattershot approach to STS education taken by various engineering programs. Despite the ability of STS courses to enhance ABET accreditation, only a small percentage of engineering programs embed STS departments within engineering schools. While available statistics suggest that engineering schools are integrating more STS departments and courses at the undergraduate level, few course offerings at the graduate level attend to the formation of nontechnical STS skills. [7] The following section describes the UVA DEI graduate course developed and taught in fall 2022.

STS/MAE 6592 – How Engineering Impacts Diversity, Equity, and Inclusion

Course Description and Objectives

Why choose engineering? Often, individuals choose to become engineers because they have a passion for creating knowledge and technologies that serve society. Despite the wealth of data and impressive advances in the field of engineering, experimentation also raises several serious ethical, social, and public-policy concerns. Though scientists and engineers have often maintained that their work is value free, they are now increasingly required to factor in diversity, equity, and inclusion responsibilities as they plan to conduct their programs of research. Analytical tools from STS can help engineers better understand the sociotechnical systems of the profession, including how engineering impacts DEI.

The course titled "How Engineering Impacts Diversity, Equity, and Inclusion" considers the writings of a variety of authors and a few films, representing distinctive perspectives on matters of diversity, equity, and inclusion. Through their engagement with this material and in dialogue with each other, students in the course will:

- Look historically to identify and understand instances of racism, sexism, discrimination, and bias, specifically in the science and engineering fields
- Consider their own implicit bias and how it impacts technological devices and engineered systems
- Recognize and address gaps in diversity, equity, and inclusion in their own research
- Evaluate stereotype threat and imposter syndrome in the context of DEI and how they impact researchers' mentality

Course Design and Materials

In recognition of inequity among the student population, this course requires no textbook. All assigned materials are digitally available through UVA's online learning management system. This course design choice enhances accessibility, supporting the course goal of inclusion. Foundational texts that have informed the course include *Technology Matters:*

Questions to Live With by David Nye; *Engineering Ethics: Contemporary and Enduring Debates* by Deborah G. Johnson; and *Race After Technology* by Ruha Benjamin. Based on the guiding principles outlined in these texts, the course is divided into four broad modules. In the first module, students use introspective reflection in thinking about engineering stereotypes, considering how they can challenge these stereotypes. This module explores DEI etiquette, implicit bias, confirmation bias, stereotype threat, and imposter syndrome. The assigned readings and visual materials for this module specifically focus on the graduate student experience. For example, the assigned reading for the discussion about imposter syndrome is called "The Imposter Phenomenon Among Black Doctoral and Postdoctoral Scholars in STEM" by Devasmita Chakraverty. During the in-class discussion about this reading, it became clear that the students needed a space to explore their experiences and to unpack the imposter syndrome they were able to successfully identify and overcome due to this reading.

The second module confronts history, examining cases of historical injustices in relation to DEI. This module began with a viewing of the film *Hidden Figures* and a discussion of Jim Crow laws and etiquette. Contextualizing engineering innovations and history simultaneously illustrates the interconnectedness and responsibility of the engineering profession. This case study illuminates the racial tensions and systems of oppression that have shaped and characterized American society, a perspective critical for international graduate students. In addition to spurring discussions about the role of technology and race, the film also opens conversations about bias in the engineering workplace, enabling students to draw connections to the University of Virginia. Subsequent case studies in this module include the history of eugenic science, the Tuskegee syphilis study, and algorithmic bias. The other important visual included in this module is a Netflix documentary called *Coded Bias*. Released in 2020, this recent documentary highlights what is often missing in newer technologies: better datasets. This second module provides the foundation for understanding the nuances and intricacies of engineering failures to help inform conversations about more contemporary engineering issues.

The third module uses case studies, experts, and guest speakers to address the role of engineers and engineering in DEI. Some topics included the Flint, Michigan, water crisis, digital segregation, racial zoning, microplastics, how to engage stakeholders to incorporate social inequity in coastal climate resilience, and genetically modified organisms. Guest speakers included Dr. Rider Foley, who co-wrote a piece titled "Towards Digital Segregation? Problematizing the Haves and Have Nots in the Smart City" about Harlem, New York. PhD student Valerie Michel, who co-wrote a piece titled "An Assessment of How Stakeholders Incorporate Social Inequity into Coastal Climate Resilience," also spoke to the class. Having a current PhD student present research that actively incorporates DEI provides an invaluable resource for first- and second-year graduate students who will be preparing ethical research in the not-so-distant future. The variety of experts and case studies included in module three emphasizes how engineers and engineering projects are not separate from DEI, but rather have a direct impact on DEI outcomes.

The fourth and final module of this course asks students to explore the connections between engineering and social justice. Students strive to answer the question posed by Deborah

Johnson: "Is social justice in the scope of engineers' social responsibilities?" [8] While there are many topics covered over the course of the semester, each class has their own unique interests. The remainder of the final module requires students to select a topic of their choosing, attending to a case study not fully explored earlier in the semester, or not included in the original syllabus. The students then read and research these topics and present their discussions to the class. However, the University of Virginia experienced a deadly shooting in November 2022 that changed the tone of the final module. While the intention remained the same, the final module in practice became a place to examine a different kind of engineering representation. After a few classes dedicated to discussing and processing the recent events at the university, the students worked together as a collective to establish the most realistic way to finish the semester while maintaining course objectives. The final case study as selected by this particular class was a viewing and discussion of *The Dropout*, a drama miniseries on Hulu that walks through the intricacies and nuances of the Theranos case. Students conducted additional research to fact check the accuracy of the timeline and details of the case; more importantly, they reflected on how engineers were portrayed in the miniseries. Could the students identify moments of stereotype threat, imposter syndrome, confirmation bias, and other themes identified earlier in the course? The conversation about this final case study emphasized the importance of ethical research, but also highlighted the role of media in perpetuating engineering stereotypes, both good and bad.

Assessments

Assessments for this class fall into five different categories. The first category, active class participation, includes consistent attendance, completing readings in sufficient time to reflect on the assigned topics, speaking during class, and engaging with ideas from other students and the instructor. For the second category, team discussion leadership, the instructor encourages and supports students to lead small discussion groups posing appropriate challenges, questions, or activities. The third category, discussion board responses, requires an informal reflection on the assigned material. For the fourth category, talking-point papers, students synthesize the course material more formally through important reflection pieces. The fifth and last category, a final project and presentation, consists of a review of and reflection on an individually selected topic. Adjustments had to be made for the final project and presentation to protect the mental health and safety of those enrolled in the fall 2022 class, so an additional talking-point paper took the place of the project and presentation as a final reflection. The grading rubrics are transparent in the syllabus, as well as on each individual assignment. Additionally, all assessments are graded using a learner-oriented grading approach.

Course Policies

The most important course policy creates an atmosphere of respect and trust. The course syllabus indicates that it is imperative that the classroom is open and hospitable to all class members. Throughout the semester, students should examine their perspectives and values as individuals, engineers, and people situated in a broader society and the environment. Students are encouraged to respect and appreciate the different approaches that their colleagues might share in a class discussion. Without establishing a safe physical space, this discussion-based course has little success.

Other course policies indicate an illness and other absences clause, a late work policy, how final grades are calculated, a statement about the honor code, how to establish individual accommodations, support for religious accommodations, a list of student support resources, and a flexibility disclaimer. The disclaimer at the very end of the syllabus allows each class to explore their unique interests, goals, and learning styles. Allowing for the flexibility to alter assignments and/or course material creates a more fruitful discourse.

Lessons Learned

Seventeen students enrolled during this pilot course: two in their third year, eight in their second year, and seven in their first year. A mixture of master's and PhD students represented four different disciplines – biomedical engineering, mechanical and aerospace engineering, computer science engineering, and systems engineering. It is worth noting that seven of the enrolled students were international students, while one student received their undergraduate degree from the University of Virginia. Likewise, eight students identified as female, while nine identified as male. Given this distribution, students were asked on the first day of class why they elected to take this course. The overwhelming majority stated that they wanted an environment where they could discuss and learn from their colleagues about engineering and DEI. Most of the class did not receive a formal ethics course specifically designed for engineering students during their undergraduate career. On the other hand, those students who did have an opportunity for an engineering ethics course during their undergraduate career emphasized that they still felt the need for a specific space for graduate students because of new research and career goals they had not considered during their undergraduate education.

One student commented, "This class certainly challenged my perspective as an engineer and as a human. Before this semester, I had hopes to make an impact in engineering, but I did not think deeply on how engineering impacted DEI. I learned so much about the role of an engineer and the power that I do have as a young woman in STEM. I am especially grateful for how much I learned about advocacy for myself, and more importantly, for others."

Another student said, "This was wonderful. I really enjoyed the class dynamic and the discussion-based learning. I like the framework of this course and how it encompassed engineering stereotypes and then moved into more specific cases, even ones related to UVA. I think this course should be a requirement for all engineering students, graduate and undergraduate alike. This class expanded my knowledge on my role and duty as an engineer and what that means in shaping society and DEI efforts."

It is clear based on the in-class discussions and assignments that a necessity exists for this kind of course at the graduate level. While more institutions are incorporating engineering ethics at various levels, by the time engineering students reach the graduate level, there is no uniform shared experience in the exploration of non-technical engineering issues. Some of the students in this course had extensive ethics courses based on their undergraduate curriculum, while others had none. This disparity demonstrates the imperative nature of providing a graduate level course that situates these students in their new roles. The next step for this course is to offer it again as a special topics course cross-listed with a few engineering departments. Once this course receives more quantitative feedback, the goal is to create a required, three-credit course for all first- and second-year graduate students.

Next Steps for All Educators: Creating Inclusive Learning Environments

The road to the inclusion continuum requires small but powerful changes for all educators. These changes particularly impact students in their graduate careers, as they will assume leadership roles and responsibility that holds them directly accountable for creating inclusive environments. Having inclusive role models in their education will positively reflect on their future careers. What are the small changes that engineering educators can make in all their classrooms? First, create high touch environments with consistent signage and communication between the professor and the students, maintaining safe and secure classroom spaces for communication. Second, create more personalized and proactive interactions, including relevant self-disclosure, humanizing the relationship between the student and instructor. Third, create clear performance expectations. Educators can make assumptions that students understand syllabi and policies. Providing regular feedback for students solidifies performance expectations because a calibration occurs when students receive tailored motivators. Fourth and finally, create a climate of respect and trust in the classroom. One way to establish this climate on the first day of class is to create a list of classroom norms. Holding to this agreement throughout the semester creates a model of respect that will translate to classroom discussions and activities.

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