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GIFTS: Addressing Bias in Engineering Design with a Classroom Activity

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GIFTS: Addressing Bias in Engineering Design with a Classroom Activity

This Great Ideas for Teaching, and Talking with, Students (GIFTS) paper presents a classroom activity designed to address bias in engineering design and foster social responsibility among first-year engineering students. Through analysis of real-world examples of bias in technology, students explore how cultural, personal, and societal factors influence engineering decisions and outcomes. Analysis of student reflections demonstrates the activity's effectiveness in helping students recognize their responsibility to create inclusive engineering solutions while developing specific strategies for preventing, detecting, and mitigating bias in their future engineering practice.

Motivation

Engineering education plays a crucial role in shaping future professionals who will design and develop technologies that impact society. Students entering engineering programs often view the field primarily through a technical lens, focusing on problem-solving and innovation without fully considering the social implications of design decisions [1]. However, research shows that unconscious bias in design processes can lead to products that exclude or potentially harm certain populations [2] [3]. For example, early automobile crash test dummies were designed based only on male body types, leading to higher injury rates for women in car accidents [4]. Teaching students to recognize and address bias in engineering design is crucial for developing socially responsible engineers [5]. Through this activity, we aim to expose students to examples of how bias shows up in engineering design so that they can begin to thoughtfully evaluate the potential impacts of their design choices.

Context & Objective

The "Bias in Design" activity is integrated into ENGR 101: Engineering, Design, & Society, a required first-year course that introduces students to engineering while centering social justice within their educational experience [6]. The course combines technical and social content with a goal of developing a socio-technical mindset as well as student understanding of the relevance of social justice to their future as engineers. This activity occurs during week four of the quarter as part of the "Developing Sociotechnical Mindsets" unit, building on earlier discussions of identity, belonging, and engineering decision-making. The primary objective of this activity is to help students recognize how bias impacts innovation while developing their ability to analyze the impact of engineering decisions on people and communities. Through engagement with real-world examples of bias in engineering, students learn to identify how engineering solutions can unintentionally exclude or harm certain populations. The activity challenges students to think critically about ethical considerations in engineering and empowers them to propose approaches that promote inclusivity in design while thinking about how to mitigate and/or prevent bias.

These objectives align with the course's broader goal of developing sociotechnical mindsets that bridge the gap between technical expertise and social responsibility. The activity specifically addresses one of the course's guiding questions: "In what ways do cultural, personal, and societal factors influence engineering decisions, processes, and outcomes, and how can we actively mitigate biases in these areas?" By engaging with this question through concrete examples, students begin to understand their responsibility as future engineers to create solutions that mitigate bias and increase accessibility.

Implementation

Prior to class, students complete assigned readings focused on defining bias generally, the different forms of bias (implicit, explicit, cognitive), and some examples of these types of biases. They also take at least one online Implicit Association Test (https://implicit.harvard.edu) to begin reflecting on their own unconscious biases. This preparation helps ground the in-class discussion in both theoretical understanding and personal insight.

The activity begins with a brief lecture-based discussion focused on the topic of bias. As a class, we discuss student impressions of the Implicit Association Test, the different types of bias, how bias manifests through stereotypes, prejudice, and discrimination. We point out that while engineering solutions require technical expertise, they are also shaped by the assumptions and perspectives of their creators. We emphasize that recognizing our own biases is the first step to addressing them in our work.

By starting with this discussion, we create space for students to recognize that even well-intentioned engineers can create harmful products when they fail to consider perspectives different from their own. This sets up the "Bias in Design" activity, which proceeds using a jigsaw classroom technique organized in four phases [7]:

Phase 1: Home Groups (15-20 minutes) Students are arranged into initial "home" groups of 4-6 members. Each student is assigned one of six topics related to bias in design:

- Crash test dummies and gender bias
- Facial recognition technology and racial bias
- Smart watches and accessibility
- Speech recognition technology and accent bias
- Airport body scanners and discrimination
- Exoskeletons and disability considerations

Phase 2: Expert Groups (20-25 minutes) Students regroup with others assigned the same topic to form "expert" groups. These groups analyze their assigned case by addressing:

- How the technology exhibits bias
- Which populations are excluded or harmed
- Ethical implications
- Potential strategies for mitigation

Phase 3: Home Groups Reconvene (20-25 minutes) Students return to their original groups where each member presents and summarizes key aspects of their topic. The groups then work together to:

- Identify which example represents the "most biased" and "least biased" technology
- Determine which case was the "most surprising"
- Analyze which example had the "most harmful" impact
- Each group records their conclusions on the board for class-wide comparison.

Phase 4: Full Class Discussion & Synthesis (20 minutes) In the final phase, teams share their assessments of which examples were most biased, most harmful, and most surprising. This often sparks engaging discussions about what makes some biases more problematic than others. We then shift to action-oriented brainstorming, focusing on how to prevent, detect, and mitigate bias in engineering practice. Students generate practical strategies ranging from diversifying design teams to implementing systematic bias audits. As ideas emerge, students record them on the board, building a shared resource of concrete actions they can take in their future work. This synthesis helps reinforce that addressing bias isn't just about awareness – it requires specific, intentional practices throughout the engineering process.

During Phase 4 discussions, students generate a list of practical strategies for preventing bias in engineering practice. Common themes included diversifying design teams and user testing groups, creating inclusive design checklists that prompt consideration of different user populations, establishing review processes to check for bias throughout the design process, and building in accessibility considerations from the start rather than as an afterthought.

Faculty facilitated these discussions using specific prompts such as:

- "What assumptions might engineers make that could lead to exclusionary design?"
- "How could we modify the design process to better account for diverse user needs?"
- "What concrete steps could you take in your future work to prevent bias?"

Analysis & Findings

We conducted an analysis of student reflection assignments from Fall 2023 to understand the impact of the Bias in Design activity. The reflections were completed at the end of the quarter and consisted of open-ended prompts asking students to reflect on their learning experience in the course. Despite the prompts not specifically mentioning bias or the class activity, nearly 40% of students (18 out of 46) chose to discuss bias in engineering and design in their reflections.

Analysis of these reflections revealed several distinct ways students engaged with, and internalized concepts related to bias in engineering, as shown in Table 1: Summary of Student Reflections on Bias.

Students frequently expressed surprise at learning about bias in engineering design, suggesting this content challenged their preexisting assumptions about the field. The reflections also demonstrated how the activity impacted students' views of their future professional responsibilities. Several students emphasized the importance of inclusive design, with one noting that "designing for accessibility can improve the experience for all users, not just those with specific needs." Another student committed to "creating designs that include and work for all users, not leaving anyone out."

Table 1: Summary of Student Reflections on Bias (n=46)

Category	**Description**	**Representative Quote**	**Count**
Recognition of Real-World Examples	Referenced specific cases of bias in technology	"I was shocked by how self-driving vehicles hadn't been trained to recognize people of color as effectively as they had been trained to recognize white people... It seems like a blatant issue that shouldn't have existed in the first place."	5
Personal Awareness	Discussed new understanding of bias or own biases	"Before this class, I definitely had internalized a lot of common stereotypes about engineers... After taking this class, I feel like I have moved past many of those stereotypes and feel more confident that I could belong in an engineering career."	7
Professional Responsibility	Expressed commitment to addressing bias in future work	"My personal responsibility as a future professional is to make sure my designs are accessible and that I consider everyone's needs when creating solutions. I will apply these lessons in both my career and in my everyday life."	11
Technical Integration	Connected bias to engineering methods	"Having these diverse viewpoints can help see obscure viewpoints that would be hard to identify, such as creating products that can be used by disabled people who don't have as much mobility as normal human beings."	6

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The reflections demonstrate the development of socio-technical thinking, with students recognizing that technical solutions cannot be separated from social considerations. Students showed evidence of understanding that engineering solutions must consider diverse perspectives to be effective. As one student reflected, "diverse teams create better solutions," demonstrating recognition that inclusive practices are integral to good engineering. This suggests students are developing a more holistic understanding of engineering practice that incorporates both technical and social dimensions. In addition, during the activity, faculty observed that students show significant interest in these topics, often independently exploring additional examples of bias and seeking out supplementary sources.

This integration of social and technical considerations in student reflections suggests that analyzing real-world examples of bias in engineering design helps students develop a more nuanced understanding of engineering practice. Furthermore, the frequency of unprompted mentions indicates that the activity had a lasting impact on students' conceptualization of engineering and their future roles as socially responsible engineers.

While the activity was generally successful, there were some challenges. The primary challenges that emerged centered around two key areas. First, students struggled with how you can recognize bias in the early stages of design and grappled with questions about what actions they could take, particularly when not in positions of power. This led to some discussions about the role and responsibilities of engineers in creating inclusive designs. Second, managing conversations around bias proved challenging at times, particularly when groups disagreed about the severity or impact of bias in certain examples. These disagreements, while sometimes difficult to navigate, often resulted in deeper analysis of how bias can manifest in engineering solutions and helped students develop more nuanced perspectives on the importance of inclusive design.

Conclusion

The "Bias in Design" activity provides a structured way for first-year engineering students to explore how bias shows up in engineering design technology while developing critical thinking about ethical design practices. Student reflections indicate that analyzing real-world examples helps them recognize the role of diverse perspectives in engineering and their responsibility to create inclusive solutions. The jigsaw format encourages active participation while allowing students to develop expertise in specific examples before engaging in broader discussions about bias in engineering. This activity can be readily adapted for use in other engineering courses, particularly those focused on design thinking, ethics, or professional practice. The structure allows flexibility in both the specific cases examined and the depth of analysis based on course level and available time.

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