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Pilot Study: Impact of Social Consciousness on Engineering Design Decision Making

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Abstract

One of the tasks of engineering design education is to ensure that students have a strong understanding of their customers and environments. They must understand the context of their decision-making and how it affects people in diverse communities. This requires students to see how a design may be biased toward or against a particular population and to develop sensitivity about issues of race, gender, religion, nationality, age, physical ability, and much more.

Over the last two years, a team of faculty across disciplines as well as staff specializing in diversity, equity, and inclusion have developed a set of design exercises focused on social consciousness. These exercises are designed to be completed within a single lecture (50-75 minutes) facilitated by a pair of multidisciplinary instructors and provide insight into possible biases within the design process. This paper presents the development and implementation of the exercises, including detailed facilitator instructions and guidelines for educators. These exercises have gone through several iterations in a pilot study with engineering design classes and focus groups. The pilot study shows positive feedback indicating that these exercises help students understand their design environment and identify possible prejudices before they are an issue; they also help create a more globally aware student who is prepared for positive and engaged citizenship.

Introduction and Background

Recent research in the fields of engineering and design pedagogy has highlighted the importance of social consciousness in undergraduate education [1]. Yet much of the curriculum for students in engineering and design majors remains focused solely on science and mathematics without the necessary extension of situating the design process in relevant social contexts [2]. Several researchers have reported on their efforts to consider social consciousness in the engineering curriculum. Examples include adding Socially Responsible Design content [3]; focusing on human-centered design [4]; and integrating social context, social justice, and social responsibility into engineering courses [5]. A recent research study examined the abstracts of first-year engineering design projects and discovered that a larger percentage of mostly male groups chose projects that were socially conscious when compared with mostly female groups, while the evenly mixed groups were the most represented in the socially conscious category [6].

Research on recent examples of engineering and design shortfalls have revealed the ways in which bias, as it relates to race, class, gender, and physical ability among other factors, influences a variety of design outcomes from automated facial analysis tools to artificial intelligence to location-based gaming [7,8,9]. These outcomes precipitate the need for students in engineering and design majors to identify the conscious and unconscious biases that influence their own design decisions. Questions like, “who does your design help?” and “who *isn’t* it helping?” go beyond the usual technical goals that drive the designer. By creating several self-contained exercises focused on finding and discussing these biases, we intend to provide students

with insight into their own design choices, start larger community discussions, and help Wentworth Institute of Technology (WIT) establish itself as a strong engineering school with socially aware and socially responsible students.

To address this gap in engineering design pedagogy, a team of faculty and staff from Student Affairs, Mechanical Engineering, Electrical and Computer Engineering, Interior Design, and Humanities and Social Sciences have worked together on how best to create and fit these exercises into a one-hour module for a wide variety of courses in all majors. This curriculum development aims to address the needs of both faculty and students. By developing materials and activities that address social consciousness, engineering faculty can enrich their curriculum and target gaps in their programs. For engineering students, these activities can foster the social consciousness that is often missing in curriculum and that overlooks large communities of users. As such, the exercises would be presented in various engineering design courses across class levels.

Design of the Social Consciousness on Engineering Design Activity

Inspired by the work of Mejia et al. [10], the research group developed a classroom-ready activity to examine the impact of social consciousness on design decision making. The idea of universal design and inclusive design is not new, however. Architects and interior design professionals have been teaching inclusive design in various ways for the past 20 years; therefore, the team included a professor from these fields to ensure a broad perspective on the design process. Architects, designers, and engineers are required by license and certification to design the built environment for the health, safety, and welfare of the end user. Many design and architecture programs specifically include universal and inclusive design as part of the pedagogical approach in early design studios. As a result, students are equipped to approach design problems with this lens as a fundamental design tool. However, the universal approach is not always considered integral to teaching the engineering design process.

Motivation Behind Image Choice

The first step was to implement an exercise based on a set of photos from the Center for Creative Leadership (Visual Explorer Cards). Five photos were chosen carefully, which are shown in Figure 1. These photos were specifically chosen to illustrate a spectrum of human needs and constraints within their designs. Figure 1a shows a diner setting and displays a clear design with limited explicit humanity; Figure 1b is actually two photos, juxtaposing different human needs and cultural uses of boats; Figure 1c displays both design and humanity, showing a child with a walking-assistive device; and Figure 1d shows stairs with high-heeled shoes, intended to display limited technical design choice and more humanity. The sequence is chosen to gradually show students the impact designs have on a human user, with the final photo implying that the design is *not* intended for some users.

More details on the intended discussion themes are below:

- Figure 1a, a photo of a diner counter, was chosen so that participants could easily recognize its contents. Identities implicated in the photo and offering the possibility for

discussion include social class (someone being waited on in a diner) and accessibility (lack of tactile differentiation between the salt/pepper).

- Figure 1b is a juxtaposition of two boats, intended to inspire a comparison between the needs of the users. Possible discussion themes included class, race, culture, nationality, and historical biases (the boat on the right is from Vietnam and has a history in colonialism [11]).
- Figure 1c depicts a child using an assistive device for walking. The key identities implicated are age and ability, but some discussion of gender presentation is also possible.
- Figure 1d is a pair of high heels on a staircase. The identities implicated in the photo and offering the possibility for discussion include gender identity and ableism.

Through the evolution of the initiative, the group iterated through several photos, removing those that did not seem to help students in the goals of the workshop. For example, there was a photo that contained a plain circuit board. Originally, it was intended to show a lack of a clear customer, forcing the students to make assumptions. However, the image did not propel the conversation, and so was removed and replaced. Similarly, a photo of the Great Wall of China was also selected for the first iteration. Students seemed interested in the design, but the discussion went directly to engineering design criteria: safety, liability etc. The original hope was to have discussions about culture, accessibility, and history; however this was not the case, so the image was removed. In the end, the five images in Figure 1 were chosen as the final set. Different images can be geared toward specific themes, possibly including accessibility, culture/nationality, gender, race, class, age, and more. If one wanted to use new photos, the recommendation would be to test the images in small groups to ensure the conversation tracks with the intended topics and themes.

Figure 1. [i]Visual Explorer images used for the exercises.

During the activity, students are asked to examine a photo's content rather than its aesthetic impact. Using Figure 1a as example, students should be encouraged to focus on the objects in the photo, such as the salt or sugar shaker, and not dwell on aesthetic issues such as color or camera angles.

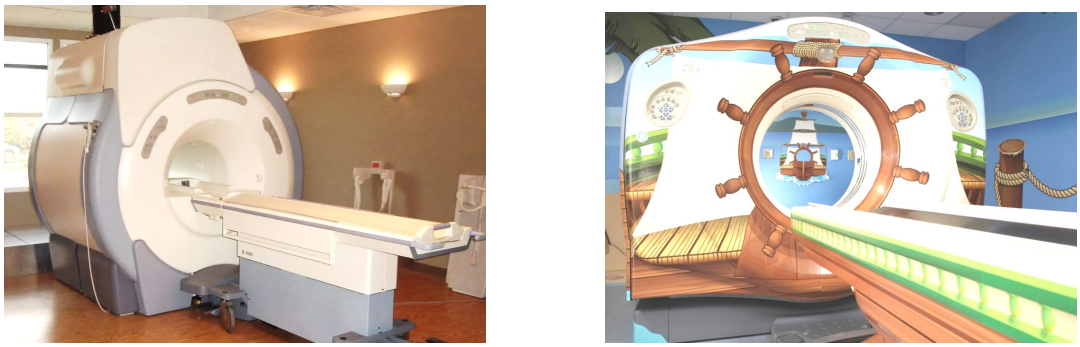
Procedural Steps

Below is the full procedure of the activity.

1. The facilitators and students introduce themselves.
2. Facilitators encourage respectful and open dialogue but explain that the room is a safe space and discussions may have imperfect "draft" language; facilitators emphasize that all participants – including facilitators – are engaged in a learning experience.
3. Facilitators explain that all participants are at different stages in the journey toward greater social consciousness and that this discussion is not the end but rather a beginning or a stopping point on the long road to equity and inclusion. All participants have their own work to do.
4. Participants are asked to get in small groups (3-5) and discuss the questions. It is encouraged that people originally seated next to each other at the start of the session are moved into different new groups to maximize the "random" group creation. This is especially important when friends or teammates are sitting next to each other when the exercises begin.
5. In their small groups, students examine a photo displayed on the screen and discuss what they see. They are prompted with the same questions for each photo (without explanation or context):
   - "Do you see problems?"
   - "Do you see solutions?"
   - "What is its use?"
   - "Who is it for?"

   It is worth noting that the lack of explanation forces students to make assumptions on their own prior to a full discussion. Randomly assigning groups helps to mix the population and perspectives within the group discussions.
6. After 5 minutes, facilitators ask groups to report out. The participants can say anything they feel is relevant. The timing can vary based on how active the discussions are and the amount of time available, as determined by the facilitators.
7. One facilitator moderates the conversation, asking participants to share, paraphrasing as necessary to ensure the full group understands the points being made. The other facilitator writes down what groups report out in shorthand on the board. The process for this mapping is demonstrated later in this paper. Facilitators should not comment on the discussion results yet, letting the participants steer the conversation.
8. If the conversation is yielding little towards the exercise's goals, the facilitator can prompt with keywords or guiding questions. This may be especially important if the groups are focusing on the images themselves and not the contents of the image.
9. When all groups have had a chance to share, repeat steps 5 and 8 for all photos.
10. Show the MRI image in Figure 2a.
11. Facilitators discuss how the basic MRI (Magnetic Resonance Imaging) is loud/frightening, asking who might be most scared (implying children).

12. Ask participants how the decorated MRI in Figure 2b helps, particularly with children (typical answers include that it is more fun, less scary, more calming).
13. Facilitators explain how the technical functions of a design are important, but not enough. Designers should also understand if some people or communities are not considered in design, with respect to age, ability, race, or other identifiers.
14. Revisit the original five pictures (all at once) and ask participants to rethink their original answers, focusing now on potential areas of bias. Pose a new question: "Who is this *not* for?"
15. The facilitator that was taking notes and marking common themes can steer the conversation, explaining how some of the answers from the earlier steps were categorized.
16. The facilitator can also provide additional context for pictures, for example discussing the cultural differences between the boats in Figure 1b.
17. Participants should be prompted on next steps and additional resources for investigating biases and social consciousness in general.



a b

Figure 2. Basic MRI vs. Decorated MRI

The goals and objectives of the process were not shared with the students prior to starting the exercise. Students only knew that the topic was "social consciousness in design." This seemed to strengthen the impact of the discussion of bias, discrimination, or oversight in the design. Anecdotally, students commented later that when they realized the impact on the user in the MRI comparison, they had a moment of revelation regarding the other photos.

The exercise detailed here was tested in Fall 2019 in small focus groups adapted to fit WIT's undergraduate population who may have a different approach or viewpoint than students at schools with a more diverse student body. The participants were in their first and second years and from different majors. Later, the activity was tested in senior design courses in Electrical and Computer Engineering in Spring/Summer 2020 and Electromechanical Engineering in Spring 2020.

Mapping

While the students explain their answers to the original questions (step 7 from above), the facilitators should be keeping notes about those answers. It is helpful in this case to have two

facilitators: one who is calling on people and moderating the discussion, and one who is writing notes. The goal is to keep general thoughts as well as note any identities that are implicated (e.g., gender, race, class, nationality, ability). An example of this note-taking process is illustrated in Figure 3, a photo of whiteboard notes from one of the pilot study sessions. As discussed above, the research group in this study includes members from a range of disciplinary backgrounds including Interior Design, Humanities, and Social Sciences. The facilitators representing these disciplines, in addition to those from Engineering backgrounds, provide an interdisciplinary perspective that enriches the discussion and range of ideas during the mapping.

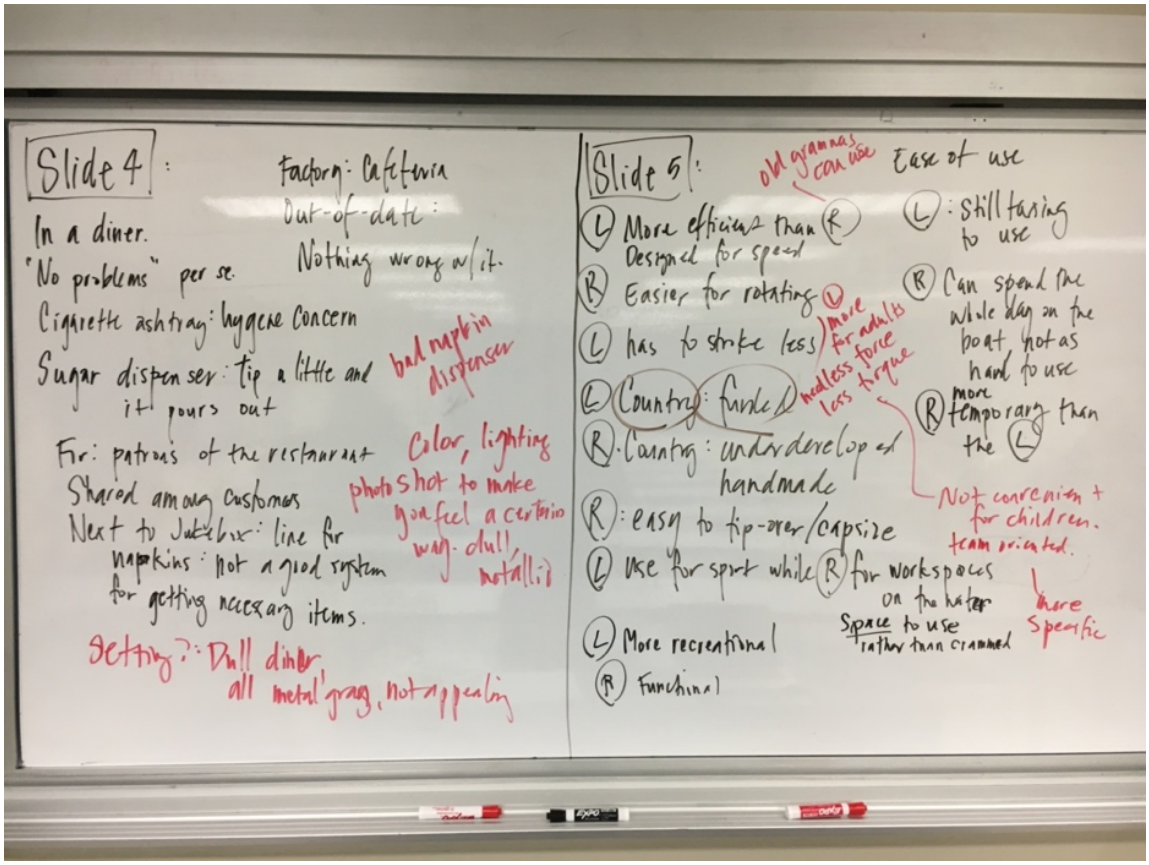


Figure 3. Example of whiteboard note-taking

Examples of the mapping between ideas and identities implicated are listed in Table 1. As can be seen in the ideas from the group discussions, students' initial responses often focus on the functionality and appearance of the items or objects in the pictures. In the discussion stage (step 12), facilitators play a crucial role in highlighting the inherently social aspects that are embedded in students' initial ideas, even if the students had not realized it. For example, in the case of the photo of the two boats (Figure 1b), students may contrast the images as 'recreational' or 'chore/job." Facilitators can direct students' attention to the fact that "recreational" is a culturally relative concept; what may be considered recreational can vary by culture. Moreover, types of recreation often implicate class and social status thus further complicating the situated meanings of certain engineered objects. Through this discussion that focuses on implicated identities,

students can gain an appreciation of how objects initially understood on a functional level can be embedded with equally important social significance.

After the exercise was completed several times, the facilitators noticed that the discussion within the groups often reveal that the students' preliminary conceptualizations of the contents in the photographs were heavily influenced by their major or disciplinary backgrounds.

Table 1. Example of Mapping of Ideas and Identities

SLIDE	IDEAS FROM STUDENT GROUP DISCUSSIONS	IDENTITIES IMPLICATED
DINER	"No problems" Out-of-date Problematic color/lighting Dull / metal / gray Ash tray	Class/working-class Accessibility (visual impairment) Race (counter sit-ins during the civil rights movement)
BOATS (TWO PICTURES)	Country Funded Underdeveloped Easier for rotating Recreational Functional Function over aesthetics Chore/job Colorful	Cultural / ethnic Class / social status Type of job Age
WALKER	Not high enough Uncomfortable Requires upper body strength Needs adjustability	Ability Age Gender (assumed the child was a girl)
STAIRS	Homeboy/homegirl Walk sideways down narrow steps! Heels get caught walking Drunk? Kidnapped / disappeared? Worn-down stairs Difficult shoes to wear	Gender Ability

Instrument for Assessing Impact and Iteration

An optional survey was sent to students who participated in the activities (including the multi-disciplinary focus groups and engineering design courses). This survey had two goals: (1) find

areas of improvement for future iterations of the activity, and (2) determine the impact on the students' attitudes towards the themes of the discussions.

Figure 4 shows the results of the survey. Answers were given on a 5-point Likert scale. As the survey was optional, only 20 students completed it (all 12 students in the focus group plus 8 out of approximately 60 in the design course versions). In retrospect, the survey responses are likely a result of a lack of strong incentive or encouragement on the part of the facilitators. In the future, more emphasis will be put on completing the survey.

The results show the workshop was received positively with students claiming it helped change their view of how design and identity are connected (65% positive, 35% neutral, 0% negative). Further, 40% claimed they would like to see more of these activities, either within or outside of a classroom environment (only 10% said they would not want to see similar activities again).

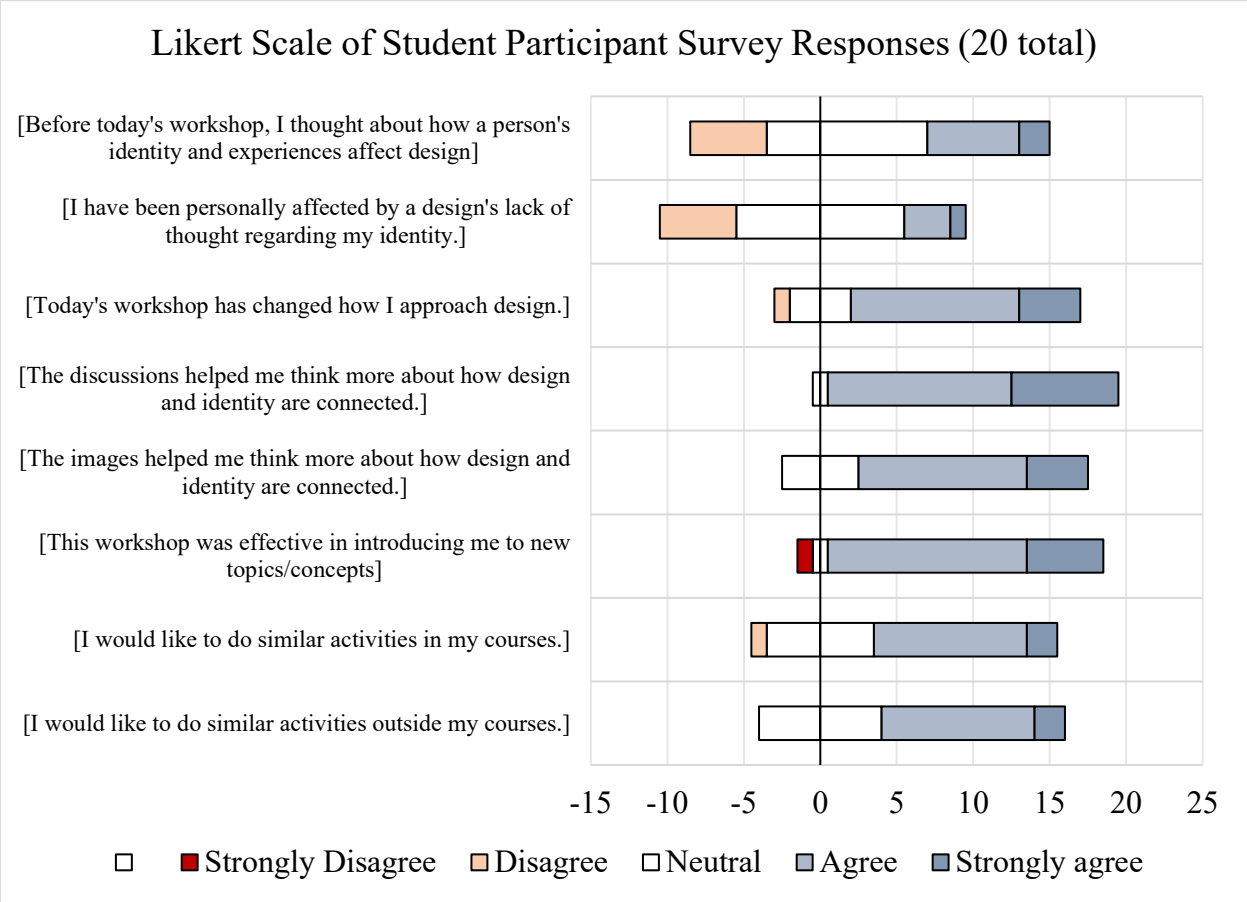


Figure 4. Survey Results

In addition to the quantitative results, two open-ended questions were provided on the survey: (1) "What part of the lesson was most interesting or thought-provoking?" and (2) "Were there any parts of the lesson that were unclear or difficult to understand? If so, what parts were they?"

Here are some examples of their responses:

"Starting out, I wasn't really approaching the images with thoughts about accessibility but now I know to look at the limitations of a design that may prevent it from being used by everyone."

"I really like the concept of the lesson and how it's to get people to think differently and out of their own shoes. I think more people need to be exposed to this, not only students."

"The realization that many common items may restrict users of a certain identity."

"I liked how we started out not know what was going on then realized we were focusing on the human aspect of the pictures."

"The exercise is a little frustrating until context is provided but was useful once we started looking through the right [sic] lens."

Instrument for Assessing Efficacy and Accreditation

In addition to providing students with necessary opportunities to unpack their own biases and assess possible biases within the engineering design process, this module is proposed as a method through which to teach ABET skills and gather assessment data regarding ABET rubrics. In particular, the following ABET outcomes have components that are included in this activity:

- 2. Ability to apply engineering design to produce solutions that meet specified needs with consideration of **public health, safety, and welfare**, as well as **global, cultural, social,** environmental, and economic factors
- 4: An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in **global**, economic, environmental, and **societal contexts**

Future work includes a robust and modular ABET-style assessment exercise that faculty can use to gather this data. At the time of publication, a first draft was created but required further refinement and testing. Packaging a lesson plan for delivering and assessing ABET outcomes would be a potential motivating factor for faculty to adopt the module.

Discussion

This paper has presented exercises that have been developed to target students' social consciousness in engineering design. Preliminary assessment of the exercises suggests that it benefits students in several ways. According to the survey results (as summarized in Figure 4), many students were unaware of the role that a person's identity can play in the design process or of the effect that such designs can have on the end user. This aligns with previous research that has highlighted longstanding gaps in mainstream curriculum and thus further supports the endeavors described in this paper [11]. Moreover, by engaging students in thinking beyond design utility, these exercises can help counter prevailing dichotomies between the social and technical aspects of design thinking [11]. This approach helps recontextualize students'

engineering education beyond their engineering-specific areas and instead toward the interdisciplinary contexts within which engineered products exist. It is thus imperative to introduce these concepts early in students' engineering program and subsequently address and reassess students' engagement with these questions throughout their engineering design education.

Equally important, these exercises can also benefit faculty. In addition to addressing the well-established gaps in mainstream curriculum, this paper provides accessible exercises to help faculty begin the conversation surrounding social consciousness. Engineering faculty may sometimes feel daunted by the task of addressing the social contexts and identities implicated in their designs. As described above, the exercises in this paper were collaboratively developed with faculty from Interior Design, Humanities, Social Sciences, as well as staff specializing in Diversity, Equity, and Inclusion (DEI). As such, this paper encourages engineering faculty to leverage their institutional knowledge bases by seeking out partners from departments across campus who are experts in these sociocultural areas. This approach further supports student learning by breaking down silos and acknowledging the inherent interdisciplinarity of engineering design.

Recommendations

- Preface the discussion with a brief set of "rules" regarding language, honesty, and openness. This helps participants understand they can openly share their experiences or thoughts.
- Have students participate in beginner diversity workshops to ensure that participants have the same language and concept understanding - defining diversity, inclusion, etc. This improves the communication among participants and leads to deeper conversations. This will be included in future versions of this module.
- Moderate and guide but not lead/give answers. The facilitators may need to propel or steer the conversation but should be careful not to directly provide answers.
- Mix discussion groups across majors so that they are exchanging new ideas instead of repeating the same ideas.
- Consider ways for students to foster discussion; rather than have everyone sit and write, assign a scribe so that everyone else actively participates in the conversation.
- Keep discussion groups small. Large groups more likely quell open discussion among all participants.
- Use two facilitators, one to lead the conversation and moderate who is speaking and one to record notes and map common themes and identities.
- Pair facilitators from different disciplines to ensure a better debrief, as they bring different perspectives. In this study, having one engineering instructor and one person from humanities, social sciences, or a DEI background was successful.
- Allot at least an hour for a single session. Rushing the discussions can be detrimental to a full discussion.
- Provide additional resources; this may be the start of their conversation, but it shouldn't be the end.

Conclusion

Social consciousness is a critical aspect for design; however, in the past, it was neglected or not a focus of engineering design education. Recently the balance has shifted towards a focus on universal usability.

Over the last two years, a team of faculty across disciplines and staff specializing in social diversity have developed a set of design exercises focused on social consciousness. These exercises are designed to be completed within a single lecture (50-75 minutes) and can be facilitated by a variety of instructors. Several iterations have already been made through a pilot study with engineering design classes and focus groups. The pilot study shows positive feedback indicating that these exercises help students understand their design environment and identify possible prejudices before they are an issue; they also help create a more globally aware student who is prepared for positive and engaged citizenship. Some assessment metrics were developed; however, we do not have enough data to show the effectiveness of these assessments. More data should be collected to approve the assessment metric. This assessment will continue to be refined and tested, eventually being added as a component of the baseline module. This module could then be packaged and used by any instructor in their course.

As future work, the module will be further used in design courses across the campus by first including the module in engineering and interior design classrooms and then expanding the module to a larger set of courses. The module will specifically be adapted to fit specific fields and levels, for example, in first-year engineering design courses. These new directions will necessitate bringing new faculty and staff into discussions and training, which may help the module evolve and expand into new directions.

These new directions will need to have new images, and so one future direction will focus on the selection of photos to be used, and the best practices for choosing them. This would allow future facilitators to adapt to any field of study and level.

The design of these modules requires close collaboration of people from different divisions, departments, and backgrounds. This combination of expertise has been a driving force for the success of this module, and future work will include codifying what worked well for this team and recommendations for interdisciplinary work.

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