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Exploring Engineering Student Perspectives on Positionality in Design for 'Social Good' Collaborations*

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Collaborations within engineering student teams and among student teams and community partners, end users, and other stakeholders are an integral part of design projects that can support positive social impact. Engineering programs and experiential learning opportunities that emphasize positive social impact are becoming increasingly popular. These programs, focused on what we collectively call "design for social good," often lack explicit consideration of the role of positionality, which can be defined as the ways an engineer's and other stakeholders' identities shape relative social and political position in a specific design context. Without sufficient consideration of positionality, engineering students are not likely to fully recognize and reflect on broad problem contexts, diverse perspectives, or power dynamics among themselves and other stakeholders, nor understand how personal values and biases influence design decisions, ultimately affecting the effectiveness of design solutions. Moreover, empirically-based pedagogy on the consideration of positionality in engineering design work is lacking. To support the exploration of the effects of positionality in engineering design, this research characterized the ways engineering student designers conceptualized their positionalities in early-stage design for social good projects. A written reflection activity, followed by a semi-structured interview, was conducted with five engineering students engaged in design for social good projects. Key findings included (1) connections between participants' own minority identities, related life experiences, and conceptions of positionality in engineering design, (2) a range of the types of conceptions related to positionality across participants, and (3) characterization of the ways in which participants' conceptions changed as a result of participation in this research. We end with recommendations for the development of engineering design education strategies to improve the consideration of positionality for engineering students engaged in design for social good projects, with implications for stakeholder engagement and partnership-building skill sets.

Keywords: design; positionality; identity; student; engineering; education

1. Introduction

Engineering programs and experiential learning opportunities that emphasize positive social impact are increasingly in demand [1]. Often described with terms like humanitarian, sustainable, social justice, etc., we call these sociotechnical approaches "design for social good" for the purposes of this research. In design for social good work, differences in identities among engineering designers and other stakeholders are especially common and typically feature situations where engineers hold privileged identities compared to other stakeholders. These identity differences make it especially critical for an engineer to consider positionality, which is defined as the ways an individual's identities affect their social and political position in a given context [2], and make design for social good a natural starting place for the exploration of the role of positionality in design. In the context of engineering design, positionality may influence how an engineer seeks out and interprets information, as well as how an engineer applies their own power and privilege in making design decisions. Without sufficient consideration of positionality, engineering designers are not likely to fully recognize and reflect on broad problem contexts, diverse perspectives, and power dynamics among themselves and other stakeholders, nor understand how personal values and biases influence design decisions. A lack of sufficient consideration of positionality may lead to ineffective collaborations within teams and among engineers and other stakeholders, ultimately affecting the outcomes of design solutions.

The positionality of engineers affects decision-making throughout a design process [3], including during its earliest stages when problems are defined, requirements are specified, and initial concept solutions are proposed [4]. The lack of consideration of positionality limits the effectiveness of student design approaches and collaborative relationships [5], often leading to project failures [6,7]. Moreover, inadequate design approaches resulting from a lack of consideration of positionality not only waste resources but may reinforce inequities [8]. Design programs sometimes consider the reflective skills needed to address concepts like positionality in a

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limited way, if at all [9–12], and the literature lacks discussion of training on positionality in engineering design [13]. In addition, empirically-based pedagogy on the consideration of positionality in engineering design work is lacking. Further, from a research perspective, the ways in which engineering designers consider or neglect positionality when developing design approaches have not been thoroughly explored [13]. With these gaps in mind, research on engineering design students' awareness of their positionalities in their design work is a necessary step to connect positionality to more familiar engineering skills and design approaches. To support the exploration of the role of positionality in design, this research characterized the ways student engineering designers conceptualized positionality during the early stages of design for social good projects.

2. Background

Literature on (1) identity and positionality in general, (2) the specific impacts of positionality in engineering design, and (3) efforts to teach concepts related to positionality in engineering and other design fields are summarized in this section.

2.1 Identity and Positionality

An individual's positionality, defined as how their identities affect their social and political positions [2] fundamentally influences how – and how well – a design process is implemented [5, 13]. There are several key characteristics of positionality that may shape interactions in design. Positionality can be thought of as *relational* because the positionality of an individual towards others changes depending on how they relate to the identities of the people they interact with [3, 14, 15]. Positionality is also *contextual* because it is shaped by the circumstances and environment surrounding interactions [14, 15]. In addition, positionality is *intersectional* because the collective identities of individuals are more than the sum of their parts and typically interact in ways that perpetuate existing social norms and inequities [15], and affect stakeholders, engineers, and their design work. Positionalities are also *complex* and often *complicated* [16] because many different identities are held by an individual, the same or different identities may be assigned to that individual by different people at different times [17], and positionalities are often difficult to explicitly understand, account for, and even name [16].

Positionality is distinct from identity in that positionality is not a trait assigned to or by an individual, but is instead determined dynamically through interactions between individuals [2]. Myriad types of identities contribute to positionality, including commonly conceptualized categories like race, ethnicity, gender, sex, and age, but also include other categories like national origin, political affiliation, personality traits, education, professional experience, etc. [18–21], each of which may be more or less relevant to shaping positionalities in a given context. Moreover, a specific identity may function as a social identity, which groups people together, or as a personal identity, which distinguishes an individual from others in a particular group to which they are connected [22].

2.2 Roles of Positionality in Engineering Design

In engineering design, it is often incorrectly assumed that an engineer's good intentions are enough to make up for gaps in their understanding [8]. However, a reflective awareness of the roles of positionality in (1) assessing contextual factors in design, (2) managing interpersonal dynamics, and (3) accounting for intrapersonal dynamics (i.e., personal perceptions and attitudes) is necessary for engineers to apply sociotechnical design approaches effectively. For example, literature has shown that an engineer must recognize and effectively account for contextual factors like broad structural, historical, and cultural problem contexts [23], as well as power dynamics among themselves and other stakeholders in design work, both of which are dependent on an engineer's positionality [5]. Similarly, biased or uninformed attitudes and perspectives towards the stakeholders and contextual factors connected to an engineer's work, which can arise from a poor understanding of positionality, have been shown to negatively influence interpersonal interactions among engineers and stakeholders [3]. In addition, reflection is required for an engineer to effectively account for the potential roles of their identities and personal motivations [20], as well their assumptions, values, and biases [13] in their design approaches and stakeholder relationships. Fig. 1 visualizes the ways that an engineer's positionality functions as a lens that shapes their perceptions and behaviors related to the personal, interpersonal, and contextual elements of a design problem.

Despite the importance of positionality in engineers' approaches and the frequent failures in professional and student design for social good projects, the ideas that engineers are objective and that their identities are separate from their design work persist [24]. This culture of depoliticization in engineering communities separates and devalues social or non-technical elements relative to technical elements of design work, creating a false sense of technical/social dualism and discouraging critical assessment of social structures and norms [12]. As a

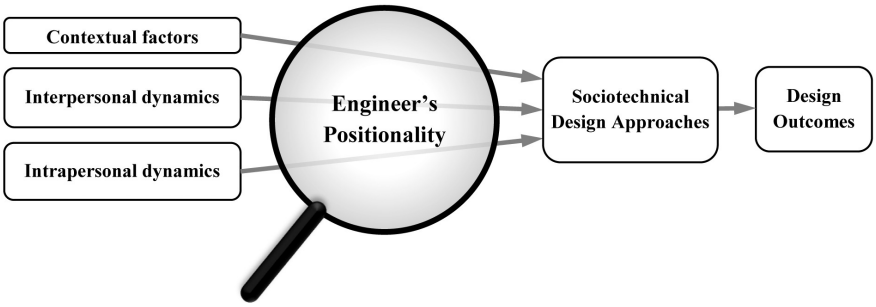

Fig. 1. The roles of positionality in engineering design.

result, student engagement with social welfare has actually been shown to decline over the course of an engineering education [25].

There are many design cases that illustrate the consequences of neglecting the role of positionality in professional and student design for social good practice, even if identity and positionality are not always explicitly named as factors. One example is the design of backdoor wheelchair access ramps in the US that enable entry, but separate users from others who can walk through the front door of the same building. In this example, the designers involved failed to fully recognize their assumptions about intended users [26]. Another case describes an international development project during which, to their own admission, US students and faculty inadvertently projected their own cultural, economic, and political norms, as well as their outsized interest in product development as engineering designers, onto local contexts and partners in Nicaragua, again resulting in project failure [7]. While literature has described multiple ways in which positionality is important in engineering design, few studies have explicitly studied identity or positionality, and no studies considered the multiple different ways that positionality may affect design decisions and processes, as shown in Fig. 1. How each of these factors come together to influence engineering design and designers, as well as how different engineering designers conceptualize and integrate concepts related to positionality into their work, have not been studied.

2.3 Strategies for Teaching Positionality and Related Concepts in Engineering Education

One framework that offers insight into the development of skills related to the consideration of positionality is the Developmental Model of Intercultural Maturity (DMIM) [27], which names specific attitudes and behaviors that represent initial, intermediate, and mature levels of development in conceptions of cultural differences. The DMIM is of particular interest in the study of the roles of positionality in design because it provides a relatively simple, discreet way to conceptualize and communicate the complex attitudes different people may hold towards one another. In this study, we used the DMIM to support data analysis and the development of data collection tools.

In the DMIM, culture is typically connected to differences in national, regional, and racial or ethnic identities. According to the Oxford English dictionary, however, culture may be defined more broadly as "the customs, arts, social institutions, and achievements of a particular nation, people, or other social group" [28]. Therefore, the DMIM may reasonably be applied to the broader set of identities that shape social groups, as well as interactions among people with differences beyond their geographic and ethnic or racial identities. Examples of immature conceptions of culture described by the DMIM include assuming unfamiliar perspectives are wrong or having limited awareness of personal values and differences across cultures. Intermediate conceptions are characterized by a willingness to interact with others without judgment, but not at the expense of one's own identity or comfort, or experiencing tension between internal and external definitions of identities. Mature conceptions include the ability to operate in and intentionally shift between different cultural mindsets or worldviews, consideration of others' identities in a global context, valuing differences in interactions with others, etc. Each level of maturity is further divided into cognitive, intrapersonal, and intrapersonal domains. In addition, the development of identity according to the DMIM has been characterized as 1) circular or iterative as opposed to linear, and 2) tending to facilitate stronger interpersonal relationships as people develop over time [29].

Research in applied disciplines outside of engineering has also shown that the awareness and consideration of factors related to positionality can be improved through educational interventions. Researchers working in fields like social entrepreneurship [30] and global leadership [31] have developed and implemented education to improve students' fundamental conceptions of

their own practice, demonstrating that poor awareness of biases and positionality may be improved through targeted education. Our use of the DMIM is intended to support the clarity and transferability of our findings and recommendations for similar educational efforts in engineering.

3. Methods

Our goals were to characterize engineering students' understanding of the roles of positionality in engineering design for social good applications, as well as their reactions to exposure to training materials and reflective activities related to positionality. This research was guided by the following questions:

1. In what ways do novice engineering designers narrate conceptions related to positionality in early-stage design for social good work?
2. What changes in conceptions of positionality in early-stage engineering design for social good do novice engineering designers report after an intervention exploring positionality, if any?

3.1 Participants

Five participants were recruited from socially-focused, co-curricular engineering design programs at the University of Michigan. General participant demographic details are listed in Table 1.

Additional participant demographics were as follows:

- Four of the five participants were non-white or of mixed race/ethnicity.
- Two participants were first-generation immigrants from a non-Western country, two identified as American/non-immigrants, and one was born and raised in a non-Western country.
- Two participants identified as LGBTQ.
- All participants were studying biomedical engineering or industrial and operations engineering.

The University of Michigan Institutional Review Board (IRB) reviewed and granted the study an exemption, and consent was obtained from each participant prior to participation in the positionality activity and interview.

3.2 Data Collection

Each participant completed a written reflection activity, followed by a semi-structured interview. Both the written activity and interview together lasted for approximately one hour. Pilot testing indicated that participants may not have the language to engage in deeper discussions about positionality without support from reference material. Therefore, participants were first presented with a document containing definitions and examples of key concepts to ensure that all participants were equally familiar with and equipped to respond to the reflection activity and interview. The information presented to participants is provided in Appendix A as well as summarized below:

- Definitions of identity and positionality.
- Definitions of early-stage design activities and design for social good.
- Examples of general ways in which positionality may influence design, summarized from literature (e.g., 7, 16, 17, 23).
- A list of 23 possible categories of identities with definitions for each.

After being presented with this information, participants were prompted to briefly describe design decisions within a single, past or ongoing, design for social good project in writing, as well as ways that their positionalities may have affected related design activities. Participants were given the option to refer to the provided information while writing. Written responses were then used to ground questions in a subsequent interview that prompted participants to explore how their various identities and positionalities may have affected their design work. Both the written activity and interview were conducted in a single session over Zoom.

To support validity, the development of the activity and interview protocols was guided by (1) socially-focused design literature describing interactions among identity, stakeholders, and problem context [7, 23, 32–34], (2) the DMIM [27], which has been shown to be an effective framework for the development of interview instruments for studies related to identity and positionality in higher education [35–37], and (3) critical theories related to intersectionality and systemic inequality based on

Table 1. Participant demographics

Participant	Gender	Year in Program	Design Project Focus
A	Woman	Fourth	Health product design for a low-income context
B	Man	Second	Health product design for a low-income context
C	Woman	Fourth	Environmental sustainability design for a high-income context
D	Non-binary	First	Health product design for high- and low-income contexts
E	Woman	Third	Health product design for a low-income context

identity [38, 39], which have been used effectively in critical, qualitative engineering education research related to identity [40]. In addition, the protocol was piloted and refined with two representative student participants before data were collected. Example questions used in the data collection protocol included:

- Questions related to a design experience defined by the participant:
  - Can you think of a time when differences in identity between you and another stakeholder affected your early-stage design work?
  - Which of your identities do you think had the greatest effect on how other stakeholders perceived you as an engineer?
  - Are there any other significant ways your positionality may have come into play that we haven't talked about yet?
- Generalized questions about participant perceptions of positionality in design and reactions to the reflective positionality exercise:
  - Can you describe your reaction to writing and talking about your positionality as an engineer today, whether it was positive, negative, or neutral?
  - In what ways was participating in this research surprising to you, if any?

3.3 Analysis

Interview recordings were transcribed and de-identified, then data were analyzed inductively to characterize the ways participants related to positionality. Inductive analysis, which is described by Creswell [39] as the development of emergent patterns of meaning as opposed to the assignment of predetermined codes or themes, was used because limited existing literature has directly characterized engineering designer conceptions of positionality. Themes were developed iteratively, as suggested by Patton [42], to allow for a more complete understanding of the data to develop in relation to our research questions resulting in repeated evaluation of the transcripts. The development of themes was supported by a synthesis of the relevant literature on positionality [7, 23, 32–34] used to develop the data collection protocol.

We did not attempt to evaluate the overall maturity or quality of participants' design approaches or outcomes. Instead, we focused on characterizing participants' perspectives with respect to theory and published conceptions of identity and positionality, in addition to answering our research questions. Similarly, we did not always attempt to distinguish among cognitive, intrapersonal, or interpersonal domains of participants' conceptions, as cognitive reactions are not necessarily measurable with the interview protocol we used, and it was not always practical to distinguish intrapersonal versus interpersonal attitudes and behaviors with respect to our research questions.

3.4 Researcher Positionality

All authors had experience working with socially-focused design research and education efforts. The first author also had experience as a student and professional with engineering design in the US and internationally, primarily for socially-focused organizations. Therefore, our team had first-hand experience with how engineers work, think, and learn across a variety of socially-focused contexts. We acknowledge that the identities of the research team represent a limited range of backgrounds and identities. All authors identified as white, Western, and cisgender, and did not share many of the minoritized identities of the self-selected group of student participants in this research. Additionally, the authors did not share many of the less privileged or oppressed identities of relevant stakeholder groups from low-income countries associated with the design for social good projects discussed by participants in this study. As the first author conducted data collection, it is likely that his identities influenced the information participants were willing to share as well. It is also worth noting that a large portion of the literature used to support our analysis was published by scholars with similar identities to our research team, introducing another way in which diverse identities and perspectives are not represented in this research. We do not claim to be able to fully interpret all perspectives shared by our participants, nor that the data we collected are an exhaustive insight into students' perceptions. Instead, with our collective experience and positionalities in mind, we sought to provide a useful characterization of student perspectives that may support the consideration of positionality in engineering design education and future research, including research conducted by teams with complementary identities and expertise to our own.

4. Findings

The findings are divided into themes related to (1) participant conceptions of positionality in design and (2) changes in conceptions due to the reflective positionality activity and debrief.

4.1 Participant Conceptions of Positionality in Design

A range of themes emerged from the ways participants discussed positionality in connection to types of stakeholders, identities, or design contexts, including (1) connecting personal experiences to

the development of conceptions or positionality, (2) connecting engineering designers' conceptions of positionality to their identities, (3) cases where positionality was explicitly considered in design approaches, and (4) cases where positionality was implicitly or explicitly neglected in design approaches. Examples of each theme are described below.

Across participants, conceptions of positionality were frequently discussed in relation to personal experiences with different identities and contexts, many of which occurred outside of formal education and design work. As an example, when asked how positionality did or did nor factor into her design work, Participant A described how her identities related to national origin and profession, derived from experience beyond her engineering education, shaped her ability to reflect on positionality during engagements with project stakeholders:

> "I personally already have that attitude [where I try to consider differences in identity and positionality] because my family's from [a low-income country] and I've had experience working there and know the lack of resources that they have. It's not the same [as the country where my design project is located], but in general, you have to ask your stakeholders and your community partners and the people you're actually working for and designing for what their needs are. So I think [this skill] was already kind of in me, but it's probably more now as I go through it [in my design project]."

Participant A explained how she connected prior design project failures to the educational and socioeconomic identities of previous team members:

> "I've seen what happens when you forget [to account for positionality in design], because I think that happened on our team in the past, and we can see it very clearly in the [failed] design [. . .]. I think that the [educational identity] of students where we want to learn new things probably played a large factor in [these poor design decisions], as well as socioeconomic status; maybe just not thinking of 'they can't afford this' [because student team members came from wealthier backgrounds]."

> "That's the problem with us being college students. We also want experience. That's partially why we join these design teams to begin with, and I don't want to say it's greed, but they want to have a cooler engineering project and start using all these cool materials and just make decisions for [themselves] versus decisions that are benefiting the community. It's turned our prototype into something really expensive and nice, but can people actually afford it? No. So now we have to go back and re-evaluate everything because I think some design decisions were made out of selfishness."

In addition, while Participant A recognized the negative impact of her team members' failure to account for their own priorities as engineering students and positionalities towards project stakeholders, she also acknowledged the multiple, complex motivations and responsibilities experienced by students participating in design for social good projects:

> "It's hard to balance: why you join this team versus [serving] actual people that are depending on you to make this work."

Participant A also described recognizing other stakeholders' positionalities towards her during design work, while trying to separate herself from biases due to her identities:

> "I personally don't view myself by those categories like [race, gender, and religion]. I view myself more in terms of character traits [. . .]. But I also realize that other people don't view me [based on character, alone]."

Similarly, when asked about their understanding of positionality in design, Participant D named personal experiences holding minority identities as leading to the development of their awareness of positionality; especially others' positionality towards them as an engineer:

> "My identities are often not that of the average person I'm working with . . . most people I work with are white. I'm [not white]. Most people I work with are men. Most people I work with are straight. Sometimes [these identities] don't play any factor in design, but they do play a factor in the process of creating the design, like how other people perceive me and my opinions."

Participant D detailed how these experiences have shaped their career goals and interactions with design team members:

> "[Working with positionality in design is] what I'm interested in doing as a career [. . .]. I guess the concept [has] affected a lot of my decisions in all of my engineering experiences, and I realize that I have very different perspectives based on the environment I grew up in. I was often an outlier compared to other designers. and I realized how much that affected my design process versus theirs; how we interacted. I have spent time reflecting on that. . ."

In many cases, participants described positionalities within student teams as opposed to other aspects of design. For example, when asked which identities were most salient to his design work, Participant B discussed identities related to gender, sexuality, personality, and academic discipline as shaping dynamics within his design team:

> "I guess extraversion is kind of what I was speaking on before. I think it's mostly an engineering team, so I think [we are introverted and] not as inclined to make decisions."

> "The business sub-team lead is probably the one person in the team who I feel the most different from. Most of us are engineers, and he's more like an econ/business person. In general, I tend to not feel that much commonality towards people in the business college. Also, he just presents very masculine and straight, which I don't think I necessarily embody."

In other cases, participants named functions of positionality in design without making an explicit connection to the term "positionality." For example, Participant E first stated that she had not thought about her positionalities in design "at all," then described the importance of gender identity in positionalities related to cultural stigmas in a health design project in a low-income context:

> "I definitely think that because [this stakeholder is] a woman the community really trusts her and are a lot more open with [discussing menstruation], because I think that is kind of a stigma [and that her] identity is working well for her. But I think that [. . .] the men would maybe feel a little weird talking about it or just not want to."

While Participant E did not make a connection to the word positionality in her discussion, she did express understanding of concepts related to positionality during stakeholder engagement in design. Some participants also shared scenarios when they appeared to be unaware of or unable to account for the implications of positionality in design. For example, when asked if her identities may have affected any aspect of her design project Participant C responded with a seeming inability to discuss the roles of her identities:

> "We don't spend a lot of time . . . we don't plan a lot for that."

Similarly, when continuing to describe the dynamics of her design team, she reported stereotyped viewpoints and possible negative internalized self-conceptions based on her identities:

> "For example, Americans can be the team leader for this kind of event. But as [an international student], I can't. I can only be the team member."
>
> "Americans are good at this and they can make friends very fast, I think. But for me, and other [people from my country], they are more willing to do things. So the leader asks us to do things, and we will do it very efficiently."

As another example, Participant D described outright rejecting feedback from a subset of potential users rather than searching for alternative ways to incorporate users with a wider range of identities:

> "And then that person we were interviewing [to collect input from prospective users], who was a guy was like 'No, I don't like [this design element]' [. . .]. We ended up disregarding his responses because [the design element was popular with women]."

These excerpts show a range of likely positive and negative effects of positionality on design processes, from supporting deeper consideration of engineering team dynamics and stakeholder needs, to influencing an engineer's self-image or perception of self-efficacy, to gatekeeping or exclusion of some stakeholder perspectives.

4.2 Participant Changes in Conceptions Related to Participation in this Research

Participants reported a range of changes in their conceptions of positionality with respect to design work as a result of participation in this research study. Themes that emerged included (1) considering new types of identities as relevant to positionality in design, (2) connecting participation to furthering personal aspirations for design for social good, (3) training related to positionality holds more benefits for students with less developed conceptions of positionality (i.e., compared to study participants).

For example, when asked if any part of her participation in the research study had surprised her, Participant E reflected on thinking about new types of identity as related to design:

> "I think I have previously considered my gender and my academic background. But I think that the [national origin of my] family is a new idea to me."

Similarly, Participant B described the list of types of identities presented to him as more thorough than his previous conceptualization of different identities, as well as the resulting nuance in stakeholder dynamics in design:

> "Certain elements of these identities I wouldn't have necessarily thought of [. . .]. This writing today has made me contextualize [positionality] a bit more. I mean, obviously, to [my design work]. But thinking about how everybody's positionality comes together to create a certain dynamic. . ."

When asked about any positive or negative reactions to participation in this research, Participant E also reflected on connecting her own identities and life experiences to her motivations to become an engineering designer and to pursue design for social good work, describing a positive overall experience:

> "I actually really liked it. It made me think a bit more about [my design project] in a new way [. . .]. I'd always known that I was invested in it, but it was kind of cool to see how my personal identity has kind of led me to like choosing it and being so invested. And I wanted to continue working on it."
>
> "I think it was interesting looking at all the different identity types and just mentally noting which one I've thought of in my own personal life."

Despite a hesitance to acknowledge positionalities when discussing her design project work, Participant C reflected on potential future considerations about her positionality towards her design team members with different disciplinary identities and their positionalities towards her:

> "[The business students said] I'm very "engineering." They ask me not to be such an engineer because I'm showing graphs and curves and providing a lot of numbers [. . .] and [now I'm thinking] maybe I'm

> doing too much, maybe I [should think] about how you should communicate with business students.''

In contrast to Participants B, C, and E, Participant A described having reflected regularly on concepts related to positionality and not deriving additional value from participation, while at the same time suggesting that other students who think about positionality less might benefit:

> ''I personally don't care because I think about these things all the time. But for someone that may not think of all these things all the time, I'm sure that it might be useful. But I am always in my head like ninety-five percent of the time; I've already thought about this.''

Similarly, while Participant D reported no new reflections as a result of participation, they discussed questions they hoped this research would address with respect to engineering culture and positionality towards engineers with minority identities:

> ''I'm glad this research is being done [but] I've definitely thought about all of these things before. I'm curious to see the results of your research, especially on how differences in gender can affect differences in sexuality and perception in an engineering context. I feel like women who aren't straight have a more positive reception in an engineering context rather than like a gay man, for example. Because I feel like that might be associated with rejection of femininity, or like the acceptance of [masculinity]. And [. . .] engineering is a very masculine thing.''

Participants' perceptions of this research demonstrated consistent interest in the subject matter, yet highlighted a range of familiarity with terms and concepts as well as willingness and ability to engage in reflection on positionality.

5. Discussion

This section summarizes and discusses participants' conceptions of positionality in design, ways their conceptions may have changed or developed due to participation in the study, as well as limitations and implications of the study.

5.1 Conceptions of Positionality in Design

Across participants, the conceptions of positionality in design appeared to be related to personal experiences with different identities and contexts, many of which occurred outside of formal education and design work. Participants described varying levels of (1) awareness and/or acceptance of cultural and contextual differences, (2) acceptance and openness in interpersonal relationships, and (3) reflection on their own views and biases in direct connection to these experiences, all of which follows prior research in showing mixed awareness and accountability for concepts related to positionality in engineering design work [5, 6, 43]. For example, Participant D's mature conceptions of sexuality and race/ethnicity in engineering culture related directly to their personal experiences and contrasted with their potentially less mature attitude towards the perspective of their prospective male user. Similarly, Participant A offered reflections on her own motivations to participate in design for social good work, the limitations of this work, and the privilege required to participate in it, all of which she connected to her identities related to race/ethnicity, gender, national origin, etc.

As with other research on engineering student engagement with different cultures [43] and identities [5, 13], our findings demonstrated that life experiences with difference, within or beyond engineering education, may relate to conceptions of positionality with respect to acceptance of different cultures, perspectives, and contexts, open and respectful interpersonal relationships, and reflection on personal motivations, values, and biases. Similarly, the absence of exposure to, or understanding of, differences in identities and positionalities may be associated with the unrecognized personal biases displayed by some participants. Our findings also align with previous research demonstrating the limited ways engineering culture tends to engage with privilege and social responsibility [25], as well as the complexity of accounting for positionality [14].

Our data do not suggest that students with certain identities and experiences are likely to hold a certain level of maturity with respect to positionality, nor that students with specific conceptions of positionality are necessarily better prepared to design solutions for specific social problems. Participants' conceptions of positionality in design appeared to be connected to personal experiences with positionality through exposure to different identities and contexts. This finding is supported by established learning theory that connects the growth of conceptions to exposure to different contexts and ideas [44]. In addition, many conceptions reported by participants were related to identity differences and interpersonal dynamics within student teams. It seems likely that participants had more experience with positionality within the context of a student design team rather than with other stakeholders, in relation to contextual factors, or in terms of reflection on their own biases and values.

5.1.1 Possible Complications in the Assessment of Conceptions of Positionality

There are many possible complications in the characterization of students' concepts of positionality in design that may factor into the findings in this study. As all participants admitted to not having previously conceptualized some of the types of

identities or other terms and concepts discussed during data collection, it may be that they were not able to fully express intuitive or subconscious conceptions of positionality that may have had tangible effects on their design processes. Conversely, there may have been effects related to overconfidence comparable to the Dunning-Krueger effect [45], where after an initial experience with differences in identities, such as an international project trip, students underestimated the amount of remaining, context-specific learning required to navigate positionality in design. Another possibility is that students who had more experiences with diversity, such as the students in our sample, were not encouraged to grow further in an engineering education environment if they were surrounded by students with less mature conceptions of positionality. In addition, participants likely had preconceptions about the interviewer's expectations in this study or what responses were most socially appropriate. We acknowledge that in some cases responses to interview prompts may have been performative rather than representative of the conceptions of positionality that a participant would operationalize in a design project.

5.2 Changes in Conceptions Due to Positionality Training Activities

Participant reactions to being presented with information about positionality in design, writing about their design experiences with respect to positionality and identity, and discussing their conceptions were generally positive, as has been found by other experiments introducing concepts related to positionality to engineering students [13]. We also acknowledge, however, that participants who may have been less open to these activities would have been less likely to participate in the study. For example, we note that all of the participants in this study were students with one or more minority identities within engineering communities, which might be suggestive of self-selection.

As participants described new awareness of types of identities during the data collection activities, it seems likely that many students do not regularly conceptualize the full breadth of possible types of identities that they and others may hold and that may affect engineering design work, which is not surprising considering that topics related to positionality are not a typical part of engineering education or engineering culture [12, 25]. Engineering students may be likely to have encountered conceptions of identities through, for example, demographics forms and popular discourse related to race, ethnicity, gender, sexuality, ability status, etc., but may not have thought about themselves or others in terms of family or relationship status, education, socioeconomic status, national origin, or other categories in the same way, even though these aspects of identities were discussed as influencing positionality in engineering design by our study participants.

5.3 Limitations

The lack of inclusion of participants with majority identities limits the range of perspectives included in this work. Students who have fewer or different personal experiences with difference may not consider concepts related to positionality in their work in the same ways. Our research team is expanding this work to include students with majority identities in engineering. In addition, future data collection may be done by researchers with other identities to further expand the range of perspectives that may be collected from participants. Additional research may also include observational or other methods to collect data on actual student design behavior and design outcomes, as well as to explore positionality in design beyond "social good" applications, across design stages, and beyond engineering design.

5.4 Implications

These findings can support the development of design education strategies to improve students' awareness and consideration of positionality in their engineering design for social good projects and design work more broadly, with implications for interpersonal dynamics on engineering teams, during stakeholder engagement, and in partnership-building skill sets, as well as intrapersonal reflection and other engineering design skills. We propose that engineering educators support students' opportunities to interact across differences in identities and context, as has also been promoted by ABET [46] and multiple studies related to design for social good [8, 9], and to do so with the intentional goal of reflecting and learning about positionality in design. If an engineer's first experience with a certain type of difference in identity or specific implications of positionality is during a design project, they may be more likely to fail in collaborating effectively with team members and other stakeholders, and ultimately make ineffective or harmful design decisions. In addition, we suggest that students should be provided with intentional, strategic education on the implications of positionality in design to prepare them to develop the skills required to account for positionality throughout their careers, as mature conceptions likely take longer to develop than during a typical engineering program experience.

With respect to the positionality activity used in this research, it appears that simply familiarizing students with concepts related to positionality may

be valuable. Multiple participants reported reflecting on identities in new ways as a result of being presented with a more comprehensive list of types of identities than they had seen before. Similarly, while participants described reflecting on their identities and positionalities in design to varying extents, no participants had been asked to explicitly reflect on positionality in design before. It seems likely that participants' conceptions of positionality in design had not previously been challenged directly during their engineering training, which may have contributed to enabling the biased viewpoints reported by some participants to go unnoticed. Training tools related to the activity used in this study could be applied throughout a design process to encourage students to reflect and uncover potential biases in design in ways that may not happen otherwise, as has been suggested in related studies of the development of engineering students' understanding of context [23] and empathy [47]. While future work is needed to develop effective training tools and methods for preparing students to account for positionality in design, the types of preliminary training activities used in this work prompted some level of new reflections in participants and may offer a worthwhile improvement over the absence of explicit consideration of positionality in many current design projects and programs.

6. Conclusion

In summary, this preliminary study of student conceptions of positionality in engineering design found that conceptions were developed from personal experiences with differences in identities and contexts. Many of these experiences occurred outside of their formal education, and participants with various identities reported a range in maturity of conceptions of positionality, as well as openness to learning about positionality. These findings highlight the opportunity for intentional, strategic education on the consideration of positionality in design that meets engineering students where they are at and sets them on a path towards developing awareness and consideration of positionality in design throughout their careers. Such education may support the development of effective collaborations and partnerships and ultimately, the success of design for social good work, and may also support design efforts beyond engineering design for social good and beyond the early stages of design.

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Appendix A: Terms and Concepts Presented to Participants During Data Collection

Part 1: Definitions

General Definitions:

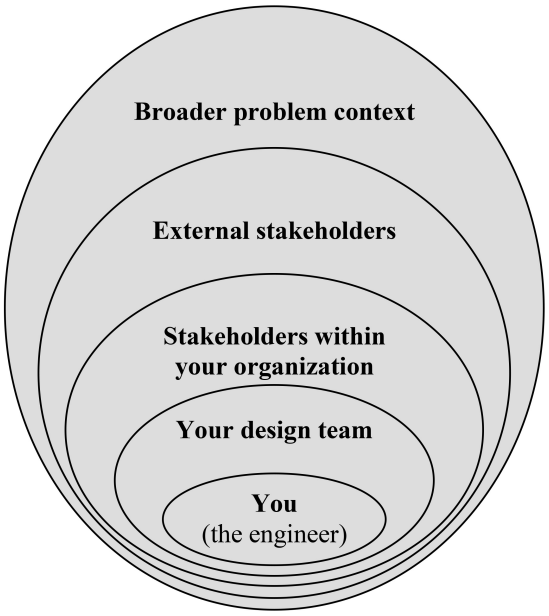
I. **Design for social good** describes work that emphasizes addressing social inequity through design as its primary focus.
II. **Early-stage design** includes activities associated with problem identification, problem definition, requirements and specifications development, and concept development and selection.
In this research we won't focus on later phases of design such as embodiment or detailed design, verification, validation, pre-production, production, launch and post-launch activities.

III. **Designing system** describes all the people and interactions that orchestrate a design process, including:
   i. The engineer (you) who collects, interprets, and applies information from other elements of the system (and from your own knowledge) to your design work.
   ii. The members of the design team you may work with.
   iii. The organization or collaborator(s) you work within beyond your design team.
   iv. The other stakeholders (users, manufacturers, investors, etc.) who have an interest in the outcome of your work.
   v. The broader context surrounding a design problem that may influence your design decisions (e.g., socio-cultural factors, the physical environment, technical or manufacturing constraints, or wider political, economic, or institutional considerations).

   These definitions are not all-inclusive nor are the boundaries exact, but as a concept a 'designing system' may be useful to describe all the different factors that you may explore or interact with as an engineer throughout a design process. The following page provides a visual depiction and detailed explanation of the common elements of a designing system.

Designing System Concept and Definitions:

A. The engineer (you) who collects, interprets, and applies information from other elements of the system (and from your own knowledge) to your design work.
B. The members of the design team you may work with.
C. The organization or collaborator(s) you work within beyond your design team.
D. The other stakeholders (users, manufacturers, investors, etc.) who have an interest in the outcome of your work.
E. The broader context surrounding a design problem that may influence your design decisions, including[1]:
   a. Socio-cultural factors: Work cultures, conceptions of time and timeliness, taboos, etc.
   b. Physical environment: Infrastructural factors; geographical and environmental factors.
   c. Technical factors: Manufacturing and industrial factors, technological factors.
   d. Social systems and structures: Institutional factors, Public Health factors, Political factors, Economic factors, etc.



Identity and Positionality Definitions:

IV. **Identity** can be defined in many ways, but we'll start by describing it as your idea of who you are based on the meanings you attach to particular roles you play in society. Many different identities, such as your gender identity, racial or ethnic identity, age, professional identity, and others, make up your overall identity.
V. **Positionality** is how your identities affect your social positions in a given context. This includes how you see or position yourself, as well as how others see you. It may be helpful to think of positionality as the ''verb'' form of identity, or how your identities shape your interactions with the world around you.

   Examples of possible roles of an engineer's positionality are provided below:

   Positionality example 1: The types of stakeholders, design problem context, or assumptions (based on personal experience) you include or exclude from information gathering activities may be influenced by your identities.

   Positionality example 2: The quality of the interaction between you and project stakeholders may be shaped by both your identities and theirs, which can impact the information you are able to collect from them.

[1] Adapted from Aranda Jan et al. (2016) *Towards a framework for holistic contextual design for low-resource settings.*

Positionality example 3: How you interpret information collected from stakeholders or research on design context may be influenced by your identities (e.g., related to your experiences or background).

Note that in each case, the impacts of your positionality as an engineer may be **positive** or **negative** on your design process. Similarly, in each case many types of identities may come into play, as will many types of designing system elements (e.g., stakeholders and aspects of problem context) that you might interact with.

Types of Identities

Identity Type[2]	Description
Age	*Numerical and/or categories like "middle aged" or "young adult".*
National Origin	*The country or countries you were granted citizenship in at birth.*
Citizenship and/or Residency	*Current countries where you hold citizenship or legal/de facto residency.*
First Language	*The language(s) you grew up speaking fluently.*
Geographic Location	*The past and/or present locations you primarily live and/or work.*
Race and/or ethnicity	*Race refers to the concept of dividing people into groups on the basis of various sets of physical characteristics and the process of ascribing social meaning to those groups.* *Ethnicity typically describes the culture of people in a given geographic region, including their language, heritage, religion and customs.*
Gender	*Gender refers to the socially constructed roles, behaviors, expressions and identities of girls, women, boys, men, and gender diverse people.* *Sex is usually categorized as female or male but there is variation in the biological attributes that comprise sex and how those attributes are expressed.*
Sex	
Sexual Orientation	*Emotional, romantic, or sexual attraction to other people (independent of gender identity).*
Religious Beliefs	*Spiritual or religious affiliations or beliefs.*
Political Ideology	*Ideological or party alignment with respect to political ideas.*
Other personal values or beliefs	*Any other value system or beliefs you implicitly or explicitly subscribe to, including but not limited to those you were raised with.*
Socio-Economic Status	*May include actual wealth and others' perceptions or assumptions about your socio-economic status.*
Ability Status	*Includes physical and/or mental ability status.*
Education	*Formal education or training.*
Physical appearance	*May include body shape, height, apparent health, physical attractiveness, style of dress, or other features that may influence others' perceptions of you.*
Personality traits	*May include extroversion and introversion, assertiveness or confidence, and other traits that influence others' perceptions of and interactions with you.*
Personal interests	*Hobbies, areas of expertise outside of design, etc.*
Family & Relationship Status	*Married, with a long-term partner, single, etc.;* *with or without children, grandchildren, or other dependents;* *with or without siblings or other family members.*
Personal connections	*People or communities you are connected to or associated with, whether or not you share specific identities with them.*
Professional Connections	*Any relationship or acquaintance with a person or network of people whose professional work relates to your own.*
Professional Position	*Professional title and status in organizational or wider professional hierarchies.*
Professional Expertise	*Professional skill sets and knowledge that may influence your perceptions or design approaches.*

Part 2: Participant Activity: Exploring effects of your positionality as an engineer on your work.

Step 1. Describing a "Design for Social Good' Project

Please choose a current or past design project that exemplifies your 'design for social good' work, then provide the following information about your project:

- Project name.
- Overall project purpose.
- Person or organization in charge of the design process.
- Your role in the project.
- Current project status (and outcomes, if applicable).

[2] Identity types and definitions adapted from 1) the University of Michigan Equitable Teaching Social Identity Wheel: https://sites.lsa.umich.edu/inclusive-teaching/social-identity-wheel/ and 2) the University of Wisconsin-Madison teaching and learning library: https://learn.library.wisc.edu/reflecting-on-social-justice-foundational-concepts/lesson-1/

Step 2. Exploring Design Decisions

Please describe one or two times when a decision that you made in the front-end of the design process may have been affected by your identities and positionalities. For each design decision, answer the following:

- Please describe a decision you made during the early-stage of your design process.
- Which information sources did you primarily use to inform this decision? (E.g., your own background knowledge, members of your team or organization, other stakeholders, or by researching other aspects of the problem context. See the 'designing system' definitions above for more examples, if necessary.
- Which of your identities were most relevant to the process of making this decision, if any? (Refer to the list of identities above, if necessary.).

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