Design Across Distance and Difference: Characterizations of Remote Stakeholder Engagement and Designer Perceptions of Positionality During Front-End Engineering Design

by

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Abstract

There is a growing interest in socially engaged engineering, which emphasizes the consideration of social, cultural, environmental, and economic factors to broadly benefit society. However, current workforce training and engineering education programs do not adequately support skill sets needed to link complex societal needs and contexts to design processes. Effective stakeholder-facing communication skills and designer-facing reflective skills are needed for engineers to assess stakeholder needs, design contexts, and their own approaches as designers. These challenges are made more difficult when design is done across distance and socio-cultural differences, which is increasingly common due to remote communication and design technologies. A lack of preparation in these cases can lead to ineffective or even harmful designs, especially if effective socially engaged practices are not incorporated early in design processes during problem identification, problem definition, requirements development, and initial concept generation. Despite these complexities and persistent evidence of ineffective design solutions, engineers continue to engage in ways that imply they can navigate design work objectively and apolitically, assuming good intentions and technical skills compensate for gaps in broader understanding.

This dissertation focuses on two key, understudied skills for early stages of socially engaged design: stakeholder engagement with prototypes in remote design contexts, and designers' reflective considerations of the impacts of their positionalities and other stakeholders' positionalities on design decision-making. The first study explores strategies for remotely engaging project stakeholders with prototypes through semi-structured interviews with engineering ten students and ten practitioners. The second and third studies explore conceptions of the roles of identity and positionality in design for ‘social good’ contexts through an exploratory, interview-based study of five undergraduate students and a larger, interview-based study of ten undergraduate students and ten practitioners.

Regarding remote stakeholder engagement with prototypes, student and practitioner participants reported overlaps between many in-person and remote approaches, as well as strategies for adapting to remote engagements. Four distinct strategies tailored to remote engagements emerged from the findings including the use of third-party, in-person facilitators and various ways to share digital and physical prototypes asynchronously. Participants also discussed implicit consideration of stakeholder identities, such as age and professional position, in selecting appropriate strategies, and reported learning these skills on the job rather than through formal education. While student participants discussed mixed perceptions of the effects of remote engagement on design outcomes, practitioners described remote, hybrid, and in-person engagements as equally effective, highlighting gaps between student and practitioner skill sets.

The studies of designer conceptions of positionality revealed that even among participants with personal interest in identity and positionality in design, conceptions were self-reported as implicit and limited by a lack of language and free discussion within engineering design communities. Participants also cited exposure to differences in identities and contexts, many of which came from their personal lives outside of design work or education, as driving the development of their conceptions of positionality.

Across all studies in this dissertation, a need for the normalization of nontechnical skills and concepts in engineering cultures and clear, explicit use of supporting language emerged. To meet these needs, engineering disciplines can build upon established language and theory from relevant social science disciplines, as well as develop curricula and educational experiences to facilitate reflective exposure to differences in identities and design contexts, which is fundamental to the development of awareness of different people, contexts, and positionality in socially engaged design.

Chapter 1 Motivation, Overview, and Background

1.1 Introduction

An increasing number of engineers are seeking educational and career paths that prioritize socially engaged design, which incorporates social, cultural, environmental, and economic considerations to support broadly beneficial design outcomes. In socially engaged design, nontechnical skills are required to evaluate and integrate the perspectives of different stakeholders and constraints of different design contexts (Walji et al., 2020), as well as to enable reflection on engineering designers' own perspectives and processes to adapt their approaches to new people and contexts (Fox et al., 2020).

The demand for socially connected design skills aligns with calls by the US science and technology education accreditation organization for broadly educated engineers who are equipped to address complex societal challenges (ABET, 2023). Yet, it is not clear that the often limited training and unstructured practice offered by many educational experiences (Loweth et al., 2021; Sienko et al., 2018) provide students with the expanded skillsets needed to independently connect human needs and broader contexts to the inputs and outcomes of their design work (Mattson & Wood, 2016), nor is it clear that engineering designers are prepared to situate themselves in their work in ways that enable accurate consideration of their own capabilities and limitations. Student design projects (Smith et al., 2020) and professional design work (Nieusma & Riley, 2010) may instead put partner communities — internationally or in the US — at risk of receiving ineffectual or even harmful design solutions when design problems and processes are inadequately understood and executed.

The problems caused by inadequate engineering design training and practice are illustrated by many documented cases of failed engineering initiatives with repeating stories of poor consideration of stakeholders, poor data collection practices in early design stages, and biases, oversights, and power imbalances between engineers and users due to. Examples include 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 (Nieusma, 2004), or a solar cookstove project in Sub-Saharan Africa where students discovered only after implementation that cooks did not perceive traditional cooking systems to be lacking in the first place (Mazzurco & Jesiek, 2014), or a technology development project in Nicaragua where US students and faculty projected their own cultural, economic, and political norms, as well as their outsized interest in technical product development as engineers, onto the local context and partners, which ultimately led to the breakdown of the project and reinforcement of existing power dynamics (Nieusma & Riley, 2010).

The risk of subpar engineering design outcomes is especially high when effective socially engaged practices are not used from the early stages of design, which include problem identification, problem definition, requirements development, and initial concept generation activities (Cooper, 2019). These early design stages are characterized by high levels of uncertainty (Gupta & Wilemon, 1990) and present unique challenges to engineers, as the understanding of a design problem and potential solutions often develop through relatively unstructured iteration (Dorst, & Cross, 2001). Case studies have demonstrated that the success of new products depends upon the quality of the execution of the front-end (Khurana & Rosenthal, 1998); many times, product failures are a result of critical decision errors made during these phases that could not be cost-effectively rectified later (Cooper, 2019).

Studies have also stressed engagement with stakeholders during the earliest phases of engineering design, leading to the definition of product requirements that better fit the needs of end-users and other stakeholders, and are suited to the context in which they will be deployed (Anderson & Crocca, 1993). Gathering meaningful information from stakeholders during a design process is difficult, requiring engineers to draw upon nontechnical skill sets to overcome communication and disciplinary boundaries and gather relevant information (Mohedas et al., 2014). In addition, an engineering designer must be able to reflect on their own role in a design process, including interactions with stakeholders and potential biases in their incorporation of stakeholder perspectives (Agyemang et al., 2023; Walji et al., 2020) and interpretation of design context (Burleson et al., 2020; 2023).

The challenges presented by early-stage design, stakeholder engagement, and reflective design practices are exacerbated when physical distance and differences in stakeholder backgrounds and contexts constrain communication and intuitive understanding between engineering designers and other stakeholders, where high complexity and diverse perspectives must be interpreted and accounted for. Despite the sharp contrast between the fuzzy nature of early stage, socially engaged design activities and the structured applications of engineering science that are the focus of most engineering training, and despite evidence engineers have historically failed to directly contribute to social justice goals (Leydens & Lucena, 2017), the idea that engineers can navigate social complexity through objective, apolitical engineering design work persists (Passow & Passow, 2017). In the case of socially engaged engineering work, it is often assumed that an engineer's good intentions are enough to make up for gaps in their understanding (Leydens & Lucena, 2017).

1.2 Background

1.2.1 Prototyping in remote stakeholder engagement

1.2.1.1 Prototyping practices for stakeholder engagement

According to Camburn et al. (2017), prototyping should be applied strategically and in a way that is appropriate for a given context. When prototypes are used without a particular purpose or strategy, resources dedicated to prototyping can be perceived as wasted (Lauff et al., 2019). Moreover, inadequate prototyping and stakeholder engagement practices can ultimately lead to project failures if quality stakeholder input is not collected and incorporated effectively (Cooper, 2019; Hansen & Özkil, 2020). In addition, because prototypes can be used in a variety of contexts and have context-specific advantages and disadvantages, strategies for how to effectively use prototypes are needed for different use cases (Viswanathan et al., 2014). Multiple tools have been proposed to guide the use of prototypes across engineering design activities. For example, Dunlap et al. (2014) proposed a heuristics-based tool to support designers in developing prototyping strategies, Menold et al. (2017) developed a seven-part framework to support novice designers in developing prototyping strategies, and Jensen et al. (2016) summarized related strategies from a review of 81 studies on prototyping in engineering. Few tools are available specifically to support the use of prototypes for stakeholder engagement, however, where engineers must communicate effectively with a diverse range of stakeholders outside of the design team.

Deininger et al., (2017, 2019), Viswanathan et al., (2014), and others have called for improved curricula to help engineering students understand the value of, and strategies for, prototyping, especially in information gathering design activities like stakeholder engagement. While engineering students have been found to use a variety of prototyping strategies, they may not be explicitly aware of the range of types of prototypes available (Lande & Leifer, 2009). Similarly, Deininger et al. (2017) found that while novice designers' prototyping practices sometimes reflect recommendations found in literature, other prototyping skills are used infrequently and without intentionality in activities like stakeholder engagement.

The front-end of design is broadly defined as including background research, needs finding, problem scoping and definition, requirement elicitation, specifications development, concept generation and concept development (Atman et al., 2007). Time spent in these stages of design is key to directing the rest of a design process in the right direction, and ultimately towards successful design outcomes. One part of front-end design is stakeholder engagement, for which prototypes are a necessary tool. The type of prototypes used, what questions are asked, and which stakeholder is engaged all affect the information collected by designers (Deininger et al., 2019), and therefore affect design outcomes. Though prior research has established the importance of contextualized, intentional use of prototypes in front-end design, specific guidance for prototype usage is understudied (Coulentianos et al., 2020a; Deininger et al., 2019; Hansen & Özkil, 2020).

Examples of relevant studies that characterized prototyping strategies for stakeholder engagement in front-end design include Coulentianos et al. (2020), which explored prototyping behaviors of global health design practitioners working in low- and middle-income countries and identified the prototyping strategies used to engage and develop relationships with a wide range of stakeholders, as well as to bridge differences in culture and language. Jensen et al. (2017) mapped the use of prototypes across eight engineering design companies, finding that prototypes were especially useful early in the design process to uncover limitations and assumptions in designs. Similarly, an interview-based study (Rodriguez-Calero et al., 2020) identified 17 specific prototyping strategies used by engineering practitioners to engage stakeholders in front-end design. Although some remote engagements were included, the engagements studied were primarily in-person and differences in the application of the strategies between remote and in-person contexts were not explicitly distinguished. While the study was based on medical device designers, it includes details on how specific design contexts led to prototyping and engagement decisions with the goal of producing findings that are transferable to other design domains. The 17 strategies were further explored in another study (Rodriguez-Calero et al., 2023) focused on automotive and consumer product design in addition to medical device design, which demonstrated broad applicability in front-end design across industries. Other studies focusing on remote design have proposed a limited number of strategies such as video prototypes for engaging stakeholders remotely to communicate concepts (Bogdan et al., 2012) and to determine requirements (Brill et al., 2010). The extent to which these or other methods are used in practice remains unclear, however, and it is not yet clear whether and to what extent the general or industry-specific prototyping strategies described in existing literature translate to other design contexts, including remote design work. In addition, there is evidence that design guidance established for one context can have a negative effect on design outcomes when applied in another context, as shown in a study of design frameworks shared by globally dispersed design teams (Reimlinger et al., 2020). Therefore, there is a need to explore the transferability of previously documented prototyping strategies for stakeholder engagement in front-end design specifically in remote design contexts, as well as the prevalence of proposed or previously undescribed strategies tailored to remote design.

1.2.1.2 Remote design work

Remote engineering design work has been increasing in prevalence for decades, as have the numbers of tools meant to enable stakeholder engagements in remote contexts (Li & Qiu, 2006). According to McKinsey & Co. (Lund, 2020), the COVID-19 pandemic has accelerated the rate at which the fraction of remote versus in-person work is increasing. This report further claimed that scientific and technical jobs, such as engineering, are likely to average 1-2 days per week of remote work, as about two thirds of typical tasks in these professions can be done remotely with no productivity loss; a ratio that will continue to grow as practitioners and organizations gain expertise working remotely. Due to these trends, designers need to be prepared to work effectively in a remote context now more than ever (Lund et al., 2020). Stakeholder engagement, specifically, is increasingly taking place remotely or in hybrid (remote and in-person) modes (Sanders & Stappers, 2008), as it offers unique opportunities to designers, such as access to previously inaccessible stakeholders and the sharing of complementary skills and perspectives amongst diverse designers and stakeholders (Asadi et al., 2017).

Remote design also presents challenges to designers, however. As technology enhances designers' abilities to collaborate across distance, designers need to be especially aware of potential communication issues that are amplified in remote interactions (Baek et al., 2019). Studies have also found that teams working remotely faced obstacles related to communication and motivation (Asadi et al., 2017), team decision making (Utriainen, 2017), and in judging the knowledge and competencies of remote stakeholders (Larsson, 2007). Similarly, a study of remote design technologies and methodologies by Li & Qiu (2006) found that designer must take information that may be implicit for in-person engagements, and instead make it explicit to overcome communication barriers and to successfully engage remote stakeholders.

1.2.1.3 Tools and Training for Remote Stakeholder Engagements

Engineering students commonly struggle to demonstrate best practices in their work during front-end design activities. Students have been found to undervalue stakeholder engagements (Mohedas et al., 2020), fixate on the use of high-fidelity prototypes (Mathias et al., 2018), inadequately implement ethnography techniques (Mohedas et al., 2014), and are not likely to associate between prototype development and quality of final design outcomes (Nelson & Menold, 2020). These practices do not align with recommendations from literature, and result in superficial design outcomes. The gaps between student behavior and the practices recommended for front-end design highlight the need for improvements to engineering education (Mohedas et al., 2014). There is also a lack of educational support for engineering students regarding remote design. Students have been shown to have more difficulty with remote design than in-person, and therefore need coaching and materials to be successful in that context (Utriainen, 2017). Explicit, advanced preparation can help students overcome the challenges of remote design quicker and make better use of prescriptive design guidance (Asadi et al., 2017). New design education strategies and materials that incorporate the realities of remote design work are needed so that novice engineers can be effective in modern, globalizing design environments (Reimlinger et al., 2020).

1.2.2 Positionality in engineering design

1.2.2.1 Identity, Positionality, and the Role of Positionality in Engineering Design

An individual's positionality, defined as how their identities affect their social and political positions (Morgan et al., 2020) and resulting judgements or biases about the world around them, fundamentally influences how – and how well – a design process is implemented (Fox et al., 2020; Walji et al., 2020). There are several key characteristics of positionality that may shape interactions in design. Positionality can be thought of as relational, in that the positionality of an individual towards others changes depending on how they relate to the identities of the people or types of ideas they interact with (Alcoff, 1988; Milner, 2007; Secules, 2021). Positionality is also contextual as it is shaped by the circumstances and environment surrounding interactions (Milner, 2007; Secules, 2021). In addition, positionality is intersectional in that the various individual identities that shape it are more than the sum of their parts and may interact to form unique dynamics (Secules, 2021) that affect stakeholders, designers, or their design work. Positionalities are also complex and often complicated (Merriam et al., 2001), as 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 (Alcoff, 2005), and positionalities are often difficult to explicitly name, understand, and account for (Merriam et al., 2001).

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 (Alcoff, 1988). Myriad types of identities contribute to positionality, including commonly considered categories like race, ethnicity, gender, sex, and age, but also include myriad other categories like national origin, political affiliation, personality traits, education, professional experience, etc. (Chou, 2020; Jacobson & Mustafa, 2019; Liu & Hinds, 2012; Tien, 2019), each of which may be more or less relevant to shaping positionality in a given context. Moreover, an identity may be conceptualized 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 (Deschamps & Devos, 1998).

In engineering design, it is often incorrectly assumed that an engineer's good intentions are enough to make up for gaps in their understanding (Leydens & Lucena, 2017). 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 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 (Burleson et al., 2020; 2023), as well as power dynamics between themselves and other stakeholders in design work, both of which are dependent on a designers' positionality (Fox et al., 2020). Similarly, biased or uninformed attitudes and perspectives towards the stakeholders and contextual factors connected to a designer's work, which can arise from a poor understanding of positionality, have been shown to negatively influence interpersonal interactions between designers and stakeholders (Morgan et al., 2020). In addition, reflection is required for an engineer to effectively account for the potential roles of their identities and personal motivations (Chou, 2020), as well their assumptions, values, and biases (Walji et al, 2020) in their design approaches and stakeholder relationships. Figure 1.1 summarizes the ways that positionality comes into play in design, as described above. The contextual, interpersonal, and intrapersonal aspects of a design environment are interpreted by a designer who, to whatever extent, may reflect and become aware of their positionalities and resulting intuitive attitudes and biases, then feed their reflective awareness back into the process of factoring information from a design environment into their design approaches. The lens in the center of the visual may be seen as the positionality of the designer, but could also be applied to other stakeholders who influence design decisions.

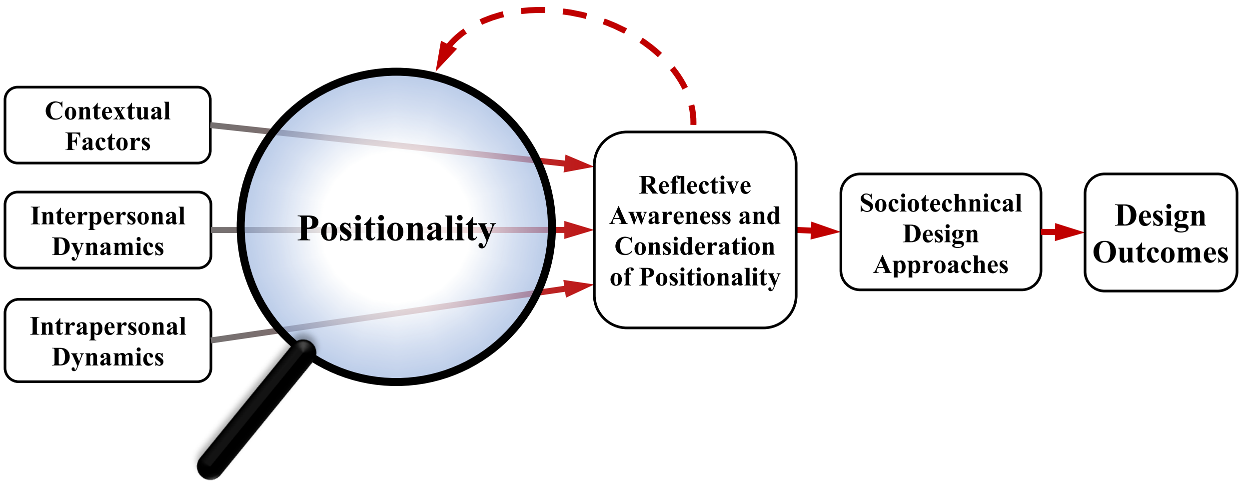

Figure 1.1 Reflective consideration and awareness of positionality in engineering design

Despite the importance of positionality in an engineer's 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 (Passow & Passow, 2017). This culture of depoliticization in engineering communities separates and devalues social or non-technical elements from technical elements of design work, creating a false sense of technical/social dualism and discouraging critical assessment of social structures and norms (Cech, 2013). As a result, student engagement with social welfare has actually been shown to decline over the course of an engineering education (Cech, 2014).

There are many cases describing the consequences of neglecting the role of positionality in professional and student design for social good practice, even though identity and positionality are not always explicitly named. One example included the design of backdoor wheelchair access ramps in the US that enabled entry, but separated users from others who could walk through the front door of the same building (Nieusma, 2004). Another case described an international development project where, 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 designers, onto local contexts and partners in Nicaragua, again resulting in project failure (Nieusma & Riley, 2010). The well-studied failure of the one laptop per child initiative to achieve its intended learning outcomes offers another example of the neglect of positionality in design for social good. Engineering and program designers have been criticized for projecting assumptions based on their own cultural and socioeconomic norms (James, 2017; Warschauer & Ames, 2010) that led to ineffective design across cultural and economic differences. The design failures in this initiative perpetuated inequitable power dynamics between the Global North and South in development initiatives, led to one of the greatest financial wastes in the history of international development, and likely caused economic harm to the intended beneficiaries due to the flooding of markets with donated goods (James, 2017) in addition to harm to individual students and educators who were disrupted by the program.

Beyond the limited available research related to positionality in engineering literature, poor consideration of positionality has been widely shown to cause designed interventions for 'social good' to be ineffective or to perpetuate, rather than alleviate, systemic injustices. Examples include academic research design and interventions for social justice (Pasque et al., 2022), social business strategy design (Wydick et al., 2016) and program design for international development (Warschauer & Ames, 2010). While current literature describes multiple ways in which positionality is important in design, few studies explicitly study identity or positionality, and no studies consider all the different ways that positionality may come into play, as are shown in Figure 1.1. How all these factors come together to influence design and designers, as well as how different designers conceptualize and integrate concepts related to positionality into their work, are not known.

1.2.2.2 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) (King & Baxter Magolda, 2005), which names specific attitudes and behaviors that represent initial, intermediate, and mature levels of development in conceptions of cultural differences. In the DMIM, culture is connected to categories like national, regional, and ethnic identity differences. It should be noted that according to the Oxford English dictionary, culture may be defined more broadly as “the customs, arts, social institutions, and achievements of a particular nation, people, or other social group,” however, so the DMIM may reasonably be applied to a broader range of identities that shape social groups.

Examples of immature conceptions of culture described by the DMIM include assuming unfamiliar perspectives are wrong or having limited awareness of personal values and other 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 identity. 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 with respect to self-authorship has been characterized as 1) circular or iterative as opposed to linear, and that 2) it tends to facilitate stronger interpersonal relationships, rather than hinder them as people develop differently over time (Magolda, 2008).

While there is little research on education related to positionality in engineering literature, research in applied disciplines 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 (Fayolle A, Gailly, 2015) and global leadership (Caligiuri P, Tarique, 2009) 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.

1.2.2.3 Positionality in other relevant bodies of literature

The study of positionality in other areas of academic research may offer transferable insights to design. Scholarship on researcher positionality in engineering education (e.g., Hampton et al., 2021) and academic research more broadly offer established, critical bodies of literature describing the relationships between scholars, research subjects, and broader research contexts. Characterizations of positionality and its role in this work, as well as the ways in which researchers may (or may not) account for it are described, as are issues related to power and bias that may be comparable to issues described in design research.

Milner (2007) emphasizes that the identities of the individual who conducts research, in terms of their knowledge, perspective, and consciousness of historical and present injustice, is an essential part of how knowledge is created and interpreted. Milner offers a critical perspective on the dynamic, relational nature of positionality, which is not neutral, but instead determined by the interests of, and relative power between, a researcher and subject or subject community. Similarly, identities like race are themselves socially constructed rather than objective (Milner, 2015; Pasque et al., 2022) and vary across contexts, depending on who assigns a given identity to whom (Pasque et al., 2022). In this way, identities may also be seen as relational instead of static and must therefore be considered in-context and from the perspective of different stakeholders if the influence of identities and related positionalities are to be understood. Moreover, the construction and assignment of identities, as well as the resulting power dynamics associated with positionality in research, are inseparable from past and present forms of oppression. Though the positionality of a researcher towards a subject need not be inherently oppressive, there is a long history of extractive, discriminatory, and otherwise harmful research practices, by design or by accident (Milner, 2007), and researchers studying issues related social injustice often hold privileged identities and outsized levels of relative power compared to their subjects, increasing the risk of harm. Identities assigned to subject groups by researchers may serve, if inadvertently, to "identify and contain" marginalized people (Pasque et al., 2022) by imposing assumptions about those identities upon subjects, and doing so without consideration of the diversity within subject populations. Research may similarly reinforce explicit or implicit notions of assimilation, where the ultimate goal is to support the integration of their subject population into ways of thinking or being that are more like the researcher's own (Pasque et al., 2022). Beyond explicit harm to participants, research done without careful consideration of positionality runs the risk of "misinterpretations, misinformation, and misrepresentations" (Milner, 2007) that may limit the accuracy and relevancy of the research and its potential impacts. Moreover, research on or with marginalized populations, when done well, has the potential to highlight the systemic injustices and their causes, so researchers who claim to work to address social inequity have a responsibility to carefully consider their positionality in their work (Pasque et al, 2022).

As a result of the well-documented risks when positionality is not sufficiently considered in research, many authors emphasize the necessity of critical, reflective practices if subjects and subject communities are to be included in research design and outcomes in respectful ways, if they are to benefit from research, and if harm is to be avoided (Milner, 2007; Muhammad et al., 2015; Pasque et al., 2022). Milner (2007) developed a framework to help shift the focus of research from answering narrowly conceived questions to a more holistic assessment of the researcher's self, relationships with others, reflective processes, and consideration of the broader context or social systems surrounding research questions and subjects. He encourages researchers to frequently ask themselves "why" and "how do I know" in order to challenge the unfounded assumptions and biases that each of us hold. Pasque et al. (2022) advocate for an activist perspective for researchers who address problems related to social inequity. The authors emphasize that half-measures towards characterizing the causes and solutions to problems of social injustice may actually reinforce the systems that caused them rather than support positive social outcomes. They claim that researchers must instead be critical and deliberate; willing to confront their own limits and ingrained biases openly, and to assign value to the expert knowledge research subjects have on their own context relative to 'outsider' researchers. The authors call for revolutionary perspectives if researchers are to meaningfully challenge the systems that cause the problems they study related to race and racism, gender and sexism, etc. Muhammad et al. (2015) echo these sentiments in the context of community-based participatory research (CBPR), which occupies a space between traditional scholarly research and applied design. The authors similarly call for equitable partnerships between researchers and communities if positive results are to be achieved, and emphasize that researcher and research team identities must be openly examined and taken into consideration if power distributions between researchers and subjects are to be equalized.

In addition to prescriptive guidance for navigating positionality, scholars who investigate researcher positionality ground their work in theoretical frameworks that are not as frequently used in design research. These frameworks, which include feminist and post-colonial theories (e.g., Pasque et al. 2022) and critical race theory (e.g., Milner, 2007; 2015) help to frame the factors that influence and are influenced by positionality, as well as characterize the systemic injustices that their research seeks to address. In summary, studies of researcher positionality demonstrate that how "research is conducted may be just as important as what is actually discovered in a study" (Milner, 2007), and that socially just goals in research cannot hope to be realized unless the power afforded by researchers' identities over subjects and subject communities is openly accounted for (Muhammad, 2015). These conclusions may have close parallels in other disciplines (Milner, 2007) including design, where an inclusive design process that takes designer positionality into account is critical if a design process if the design outcome is to be positive and worthwhile. As in scholarly research, design offers opportunities to either exclude the input of stakeholders with less power than the designer and as a result, reinforce systemic injustice, or, if positionality is taken into account as a central feature of a design process, design can instead amplify and assign value to marginalized voices through the privilege and power of designers (Sánchez-Parkinson et al., 2023).

1.2.3 Research methods

The studies in this dissertation are based in qualitative research, which excels at developing transferable findings through in-depth analysis and rich description (Patton, 2015) and is well-suited for the stated goals of the included research. Our approach aimed to describe specific practices and perceptions of participants in ways that may be transferable to a range of design contexts, but without claiming generalizability across all engineering design applications.

Specifically, semi-structured interview protocols were used for the empirical portions of this work, as this method is well-suited to the exploratory nature of the research (Creswell, 2016) and allows for a thorough, yet open-ended investigation of topic with opportunities for researchers to elicit emergent information from participants that is new to academic literature. Interview protocols emphasized open-ended questions and were developed through the generation of sub-questions related to our primary research questions, as well as through reviews of relevant literature to identify promising lines of questioning. To support quality, protocols were also piloted with representative participants, then iteratively refined before use with research participants. Interview recordings were transcribed and de-identified. Data were analyzed deductively to compare to an existing set of themes or codes (Creswell, 2016), and/or inductively, which is defined by Creswell (2016) as the development of emergent patterns of meaning from the "ground up" rather than from an existing theory, and allowing for iteration in the development of patterns, as is recommended by Patton (2015).

1.3 Motivation and Objectives

This research focuses on the characterization and development of the design skills that may support consideration of the people and contexts, both in terms of a designers' reflective processes and stakeholder-facing skills. This work is meant to address the above gaps in literature and support effective socially engaged engineering designers who better understand the nature of socially focused design problems, as well as how their own identities and positions in a design process may affect their work. Specific goals of this research are to 1) identify and characterize specific external, stakeholder-facing skills and internal, designer-facing reflective skills as they relate to socially conscious design, and 2) integrate learnings about these skill sets into usable educational tools.

1.3.1 Author positionality and motivations

A researcher's identities and positionalities affect how and what they research, and why they choose to research it. I have chosen to focus on the research topics included in this dissertation in part due to their alignment with my personal goals and experiences. In previous work in global development where design processes are more directly engaged with social issues, I have found that engineers and others must play multiple, interdisciplinary roles to effectively assess and incorporate the priorities of end-users and other stakeholders into their work, and to ultimately create a positive impact. Based on the time I've spent as a product designer working in the US, I also feel that broader skill sets and a greater awareness of one's role as a designer, as well as the context in which engineering design is done, would be valuable to most engineers across industries, and should be emphasized in engineering education. I also hope that through broader disciplinary skill sets, engineers may better understand the roles and perspectives of colleagues in other positions and from other disciplines, allowing for more effective communication and sharing of knowledge when aspects of a problem lie outside of disciplinary expertise. Reflecting on my education, I would have liked to have been prepared for these issues as a student so that I could better address them in my own work and better support my colleagues, and through this research I hope to support future design and engineering students in this way.

As a cisgender white man from an upper-middle class background, I do not share the marginalized identities held by "designees" of much of the design for social good work considered in this dissertation. The development of my research processes has been supported through periodic reviews by diverse advisors and collaborators to provide complementary perspectives. It should be noted that this team represents a limited range of backgrounds and identities, however. The perspectives of typical subjects of “design for social good” practice or research will not necessarily be represented on the research team, nor are they represented directly in the included works except through the interpretation of researchers who hold varying levels of privilege over these participants. The limits in perspectives represented in the body of work, the implications of which are discussed in each study.

1.4 Dissertation overview and contributions

Each subsequent chapter of this dissertation is dedicated to specific socially engaged design skills across distance and difference, related to either stakeholder-facing design skills or reflective, designer-facing skills. Themes across these studies reflect efforts to foster socially impactful design while navigating the complexities that are introduced by the differences in people and design contexts in socially focused design efforts, especially when meaningful physical distance and cultural difference exist between designers and stakeholders. All studies are underpinned by:

- The importance of designers’ reflective abilities: All studies advocate for the importance of reflective skills in design, which are often implicit, to enable designers to effectively consider new types of people and design contexts in their work.
- Broad consideration of stakeholders and context: The role of context and stakeholders, including community partners, end users, and others, is a common thread in all three pieces. Engaging stakeholders effectively and understanding their needs in-context are essential aspects of successful design projects.
- Learning through exposure: The research highlights the significance of experiential learning opportunities for engineering students and continued learning for practitioners.

The skills and perspectives of the participants studied were generally developed through work, educational, or other life experiences beyond formal engineering curricula.

Specifically, Chapter 2 characterizes strategies for the remote engagement of project stakeholders with prototypes when a designer and stakeholder are not in the same physical location. Strategies are examined through interview-based study of engineering students' (n=10) and practitioners' (n=10) ways of collecting information from external project stakeholders remotely. Chapters 3 and 4 explore the relationships between engineering designer positionality and design approaches, turning the lens inward to examine individual designers' processes for considering identity and positionality in their work. Chapter 3 contains a preliminary, interview-based study of engineering student (n=5) conceptions of the roles of positionality in design and learning about positionality in design, and Chapter 4 expands upon this data with additional engineering student (for a total of 10) and practitioner (n=10) data. Chapter 5 summarizes the findings of Chapters 2 through 4 with an emphasis on the overlapping implications of each study for engineering education and practice. The studies described in chapters 2-4 and the relationships between them are visualized in Table 1.1.

Table 1.1 Overview of chapters

	Chapter 2: Prototyping during remote stakeholder engagement	**Chapter 3:** Student conceptions of positionality in design for 'social good'	**Chapter 4:** Practitioner and student conceptions on positionality in design for 'social good'
Research Focus	Characterization of strategies for remote stakeholder engagement	Exploration of student conceptions of positionality in the early stages of design for 'social good', as well as student responses to training	Exploration of student and practitioner conceptions of positionality in the early stages of design for 'social good', as well as

	with prototypes during early-stage design	materials related to positionality in design	participant experiences learning about positionality in design
Sample	• 10 engineering design practitioners • 10 undergraduate mechanical engineering students	• 5 undergraduate engineering students	• 10 engineering design practitioners • 10 undergraduate engineering students
Methods	Semi-structured interviews	Semi-structured interviews	Semi-structured interviews and guided, written reflections on design experiences
Implications	*Stakeholder-facing socially focused design skills:* Strategies for remote engagement of stakeholders with prototypes	*Designer-facing socially focused design skills:* Recommendations and tools to support the development of understanding of positionality in design for students and practitioners.	

Chapter 2 Front-End Design Prototyping Strategies During Remote Stakeholder Engagement[1]

2.1 Abstract

Engineers must engage project stakeholders effectively if stakeholder needs are to be met, and prototypes are key tools for communicating design form and function. Quality stakeholder engagement in the front-end of design processes is critical in the success or failure of design projects. As remote stakeholder engagement has become increasingly common as industry trends towards distributed design, there is a need to develop the theory and practices behind effective remote design processes, which have not yet been as well-studied as in-person design. This study explored the prototyping strategies for remote stakeholder engagement during front-end design used by 10 engineering practitioners and 10 senior engineering students through semi-structured interviews. Prototyping strategies were found to overlap with many of the strategies described by prior literature that are not specific to remote engagement modes, though several of these strategies were adapted to serve different purposes in the remote context, and three emergent strategies for prototyping in remote engagements were described. Designer's perceptions of remote versus in-person prototyping strategies for stakeholder engagement in front-end design, including perceived advantages and limitations were also summarized, and recommendations for educators to better prepare engineering students for hybrid and remote work are provided.

[1] This chapter was published in 2023 in the journal Design Science (N. Moses et al., 2023) with co-authors Lauren Wojciechowski, Shanna Daly, and Kathleen Sienko.

2.2 Introduction

Engineers must effectively engage project stakeholders to design effectively, and prototypes are a key tool for communicating design form and function to stakeholders (Viswanathan et al., 2014; Lauff et al., 2020) and identifying unknown aspects of design problems from stakeholders (Jensen, 2017). Quality stakeholder engagement in the front-end of design processes, in particular, which according to Atman (2007) includes activities like problem scoping, requirements definition, and concept selection, is critical in the success or failure of design projects (Cooper, 2019; Hansen & Özkil, 2020). When engineers and stakeholders are not in the same physical location and engagement is conducted remotely, effective communication and engagement strategies may be especially important to overcome the absence of in-person communication (Asadi et al., 2017). Although remote engagements between designers and stakeholders create opportunities to share design information that would be difficult or impossible to exchange otherwise, remote engagements may also come with challenges of differences in language, cultural backgrounds, or other aspects of designers' and stakeholders' contexts, further complicating communication (Deininger et al., 2019).

In addition, remote stakeholder engagement has become increasingly common, in part due to industry trends towards distributed design teams (Reimlinger et al., 2020); a trend which has accelerated due to the COVID-19 pandemic (Lund et al., 2020). Research has shown that early-stage design phases can be among the most negatively affected by remote or distributed design collaboration (Asadi et al., 2017), however, and that both stakeholder engagement (Mohedas et al., 2020) and virtual prototyping (Deininger et al., 2019) are areas where engineering novices may struggle to be effective. In addition, traditional design guidance may become less relevant in new design contexts, such as remote design (Reimlinger et al., 2020).

Despite the increasing prevalence of remote design work, as well as the unique challenges of, and opportunities for, collaboration by distributed design teams and stakeholders, the theory and practices behind effective remote design processes have not yet been as well-studied as in-person design (Reimlinger et al., 2020; Utriainen, 2017), especially during the design front-end (Asadi et al., 2017). While specific prototyping strategies used by practitioners during stakeholder engagements during the design front-end have been studied (e.g., Coulentianos et al., 2020a; Rodriguez-Calero et al., 2020), it is not known whether and how these practices translate to stakeholder engagement that takes place remotely. This research therefore investigated prototype usage in remote stakeholder engagement during front-end design activities across engineering designer experience levels.

2.3 Background

2.3.1 Prototyping practices and stakeholder engagement

According to Camburn et al. (2017), prototyping should be applied strategically and in a way that is appropriate for a given context. When prototypes are used without a particular purpose or strategy, resources dedicated to prototyping can be perceived as wasted (Lauff et al., 2019). Moreover, inadequate prototyping and stakeholder engagement practices can ultimately lead to project failures if quality stakeholder input is not collected and incorporated effectively (Cooper, 2019; Hansen & Özkil, 2020). In addition, because prototypes can be used in a variety of contexts and have context-specific advantages and disadvantages, strategies for how to effectively use prototypes are needed for different use cases (Viswanathan et al., 2014).

Multiple tools have been proposed to guide the use of prototypes across design activities. For example, Dunlap et al. (2014) proposed a heuristics-based tool to support designers in developing prototyping strategies, Menold et al. (2017) developed a seven-part framework to support novice designers in developing prototyping strategies, and Jensen et al. (2016) summarized related strategies from a review of 81 studies on prototyping in engineering. Few tools are available specifically to support the use of prototypes for stakeholder engagement, however, where engineers must communicate effectively with a diverse range of stakeholders outside of the design team.

Deininger et al., (2017, 2019), Viswanathan et al., (2014), and others have called for improved curricula to help engineering students understand the value of, and strategies for, prototyping, especially in information gathering design activities like stakeholder engagement. While engineering students have been found to use a variety of prototyping strategies, they may not be explicitly aware of the range of types of prototypes available (Lande & Leifer, 2009). Similarly, Deininger et al. (2017) found that while novice designers' prototyping practices sometimes reflect recommendations found in literature, other prototyping skills are used infrequently and without intentionality in activities like stakeholder engagement.

2.3.2 Remote design work

Remote engineering design work has been increasing in prevalence for decades, as have the numbers of tools meant to enable stakeholder engagements in remote contexts (Li & Qiu, 2006). According to McKinsey & Co. (Lund, 2020), the COVID-19 pandemic has accelerated the rate at which the fraction of remote versus in-person work is increasing. This report further claimed that scientific and technical jobs, such as engineering, are likely to average 1-2 days per week of remote work, as about two thirds of typical tasks in these professions can be done remotely with no productivity loss; a ratio that will continue to grow as practitioners and organizations gain expertise working remotely. Due to these trends, designers need to be prepared to work effectively in a remote context now more than ever (Lund et al., 2020). Stakeholder engagement, specifically, is increasingly taking place remotely or in hybrid (remote and in-person) modes (Sanders & Stappers, 2008), as it offers unique opportunities to designers, such as access to previously inaccessible stakeholders and the sharing of complementary skills and perspectives amongst diverse designers and stakeholders (Asadi et al., 2017).

Remote design also presents challenges to designers, however. As technology enhances designers' abilities to collaborate across distance, designers need to be especially aware of potential communication issues that are amplified in remote interactions (Baek et al., 2019). Studies have also found that teams working remotely faced obstacles related to communication and motivation (Asadi et al., 2017), team decision making (Utriainen, 2017), and in judging the knowledge and competencies of remote stakeholders (Larsson, 2007). Similarly, a study of remote design technologies and methodologies by Li & Qiu (2006) found that designer must take information that may be implicit for in-person engagements, and instead make it explicit to overcome communication barriers and to successfully engage remote stakeholders.

2.3.3 Tools and Training for Remote Stakeholder Engagements

Engineering students commonly struggle to demonstrate best practices in their work during front-end design activities. Students have been found to undervalue stakeholder engagements (Mohedas et al., 2020), fixate on the use of high-fidelity prototypes (Mathias et al., 2018), inadequately implement ethnography techniques (Mohedas et al., 2014), and are not likely to associate between prototype development and quality of final design outcomes (Nelson & Menold, 2020). These practices do not align with recommendations from literature, and result in superficial design outcomes. The gaps between student behavior and the practices recommended for front-end design highlight the need for improvements to engineering education (Mohedas et al., 2014). There is also a lack of educational support for engineering students regarding remote design. Students have been shown to have more difficulty with remote design than in-person, and therefore need coaching and materials to be successful in that context (Utriainen, 2017). Explicit, advanced preparation can help students overcome the challenges of remote design quicker and make better use of prescriptive design guidance (Asadi et al., 2017). New design education strategies and materials that incorporate the realities of remote design work are needed so that novice engineers can be effective in modern, globalizing design environments (Reimlinger et al., 2020).

2.4 Methods

To explore ways in which designers employ prototyping strategies during remote stakeholder engagements, we used semi-structured interviews to characterize the strategies and perceptions of practitioner and student participants. This research was guided by the following research questions:

1. During front-end design activities, what prototyping approaches do engineering practitioners and students use to engage stakeholders remotely?
2. How do engineering practitioners’ and students’ remote stakeholder engagement approaches with prototypes compare to their in-person stakeholder engagements with prototypes during front-end design?
3. What outcomes do engineering students and practitioners perceive when using remote prototyping and stakeholder engagement strategies compared to in-person strategies during front-end design activities?

2.4.1 Participants

Interviews with 10 engineering design practitioners and 10 mechanical engineering students were conducted in 2020-21. A sample size of 20 was set based on recommendations for qualitative, interview-based research (Hennik et al., 2022). Similar sample sizes have been used in related, interview-based studies of stakeholder engagement strategies (e.g., Rodriguez-Calero et al., 2020, 2023), as well. As this study was conducted during the COVID-19 pandemic, all interviews were conducted virtually by video call.

Design practitioners and students were included to expand the diversity of engineering contexts included in our sample. There is no published set of best practices for remote stakeholder engagement, nor is it clear who, if anyone, may be considered an expert on remote stakeholder engagement since the frequency of remote design practices has changed rapidly in recent decades, as have the digital communication and prototyping tools (Li & Qiu, 2006; Lund, 2020). Therefore, the inclusion of participants with a range of ages, experience levels, and design contexts was prioritized. Our second goal in including students and practitioners was to assess any gaps between student and practitioner strategies with possible implications for the improvement of engineering education or practice.

The 10 engineering design practitioners recruited had at least three years of relevant work experience and were employed in the design of medical devices, consumer products, or automotive design. All participants had transitioned to partial or fully remote design work due to the COVID-19 pandemic. Descriptions of practitioner participants are shown below in Table 2.1.

Table 2.1 Practitioner participant demographics

Participant ID	Gender	Age	Job Title	Industry	Years of Professional Design Experience
Practitioner 1	Male	30	Mechanical design consultant	Consumer product design (internationally based)	8
Practitioner 2	Male	26	Mechanical design engineer	Consumer product design (internationally based)	3
Practitioner 3	Male	30	Senior mechanical engineering technical lead	Consumer product design (US-based)	7
Practitioner 4	Female	26	Senior engineer	Medical device design	3
Practitioner 5	Female	34	Mechanical engineering technical lead	Consumer product design (US-based)	12
Practitioner 6	Male	39	R&D director	Consumer product design (US-based)	18
Practitioner 7	Male	27	Design engineer	Automotive design	7
Practitioner 8	Male	26	Mechanical engineer	Automotive design	5
Practitioner 9	Female	24	Electrical R&D engineer	Automotive design	3
Practitioner 10	Male	32	Technical manager	Consumer product design (internationally based)	3

The 10 student participants were seniors in a mechanical engineering program in a large Midwestern university in the United States. Graduating seniors were selected to allow us to assess the strategies of engineering students at the end of their education who were about to enter the workforce. Student participants were interviewed during the month after the completion of a team-based, semester-long capstone design project course, which had been taught virtually due to the pandemic. The course required remote engagement with industry, academic, and/or community project sponsors. All student participants had some prior experience with in-person stakeholder engagements through previous design and manufacturing classes, and some had additional experience from co-curricular or other design projects. Of the student participants, six identified as male, three identified as female, and one declined to name a gender identity. As the ages and levels of design experience held by Student Participants were relatively similar compared to the Practitioner Participants, who represented a wider range of work experience levels and design industries, more detailed descriptions of student participants' design experiences are not shown.

2.4.2 Data collection

A semi-structured interview protocol was used to characterize remote prototyping practices, as this method is well-suited to the exploratory nature of this research (Creswell, 2016). The protocol emphasized open-ended questions, was developed through the generation of sub-questions related to our primary research questions, and was modeled on a similar protocol used in prior research on general strategies for stakeholder engagements with prototypes (Rodriguez-Calero et al., 2020) which did not control for whether engagements were in-person or remote. As qualitative research excels at developing transferable findings through in-depth analysis and rich description (Patton, 2015), our approach aimed to describe specific practices and attitudes of participants in ways that may be transferable to a range of design contexts, but without claiming generalizability across all engineering design applications.

The protocol was piloted with one representative design practitioner participant and two graduate student participants with subject matter expertise before data was collected from research participants. The content and organization of the protocol were iteratively refined after each pilot interview, resulting in an interview guide containing the questions used in data collection, as well as prompts for the interviewer to support follow up questions.

Practitioners and students were asked the same questions, although question language adjusted to professional or educational project contexts. For the first half of the interview, participants were asked questions about a specific design project that they selected in order to ground and give context to their responses. Broader, reflective questions were asked during the second portion of the interview to elicit general impressions of remote engagements with stakeholders beyond the selected project. Example questions asked based on specific design projects included:

- Could you describe the prototype or prototypes you used?
- What formats did you use to communicate with stakeholders remotely with prototypes? Why did you choose these format(s)?
- How did you choose which prototype(s) to use with which remote format?
- Did you use different prototypes for different stakeholders? If so, why?
- Did you use different communication formats for different stakeholders? If so, why?

Examples of broader, reflective questions included:

- Could you describe how, across your experiences, the types of prototypes you use for front-end engagements with stakeholders differ between remote and in-person engagements?
- Have you developed or do you use any specific strategies to make remote interactions more effective?
- What are the main advantages of using prototypes to engage stakeholders remotely vs. in-person during front-end design activities, and why do you feel this way?
- What are the main disadvantages of using prototypes to engage stakeholders remotely vs. in-person during front-end design activities, and why do you feel this way?

2.4.3 Data analysis

Interview recordings were transcribed and de-identified. Data were first analyzed deductively by two study team members (the first and second authors) to identify strategies for remote stakeholder engagements with prototypes using a list of strategies documented by Rodriguez-Calero et al. (2020). Excerpts from interviews were tagged using this existing list of strategies to identify the approaches our participants were using in their remote work. To improve reliability, both researchers applied codes to a subset of three student participant transcripts and three practitioner participant transcripts and discussed discrepancies in coding until consensus was reached.

Then, using an inductive approach, which is defined by Creswell (2016) as the development of emergent patterns of meaning from the "ground up" rather than from an existing theory, and allowing for iteration in the development of patterns, as is recommended by Patton (2015), we analyzed the data for strategies distinct to remote, front-end design contexts. We defined these strategies based on how our participants described their usage in their projects. We also used an inductive, iterative approach to identify participants' perceptions of the relative quality and outcomes of remote and in-person prototyping strategies for stakeholder engagement during front-end design. To support reliability, three student and three practitioner transcripts were again first analyzed by the first and second authors to define strategies and perceived outcomes and ensure comparable analysis practices before continuing with remaining transcripts. Codes were co-developed until agreed upon by each researcher, and all discrepancies between coding of specific excerpts from transcripts were discussed until a consensus was reached.

To further support reliability, the academic, industry, and educational experiences of the research team were leveraged to match our professional positionalities and expertise to research tasks. The first author has professional design experience in the US and internationally, as well as remote design experience before and during the pandemic. The second author had experience as a participant in the same capstone design project course as the student participants and was enrolled while the course was taught remotely due to COVID-19. Therefore, the first author led the initial coding of data from practitioner participants and the second author led the initial coding of student participant data. To avoid oversights or biases due to familiarity with participants' experiences, both authors then reviewed the other's work to provide a second, outside perspective to the data, and both authors then contributed to the full coding of all data. All members of the research team contributed to the iterative development of strategies and themes.

In all cases, prototyping strategies were only coded when reported explicitly by participants, in the context of remote stakeholder engagements during front-end design, and with evidence of intent, meaning that the strategy was applied with evidence of forethought and to achieve a specific goal in an engagement with a stakeholder. Cases where prototypes were only used internally within an engineering design team were excluded, as evidence of strategies comparable to those used with other stakeholders who were less familiar with the details of a design was lacking. To remove the ambiguity that would have likely been caused by attempts to discern and count the frequency of codes within individual transcripts, whole transcripts were used as the unit of analysis for strategies, meaning we counted only the presence or absence of codes within each transcript. In addition, as many prototyping and remote stakeholder engagements relate to more than one of the strategies developed by Rodriguez-Calero et al. (2020), we reported the most closely related strategies with clear evidence of intent, rather than all strategies that may be relevant to a stakeholder engagement.

2.5 Findings

Our data showed meaningful overlap between the general prototyping and stakeholder engagement practices described in prior literature, as well as clear distinctions between the two modes of engagement. We also found consistent differences between practitioner and student participants in terms of the variety and intentionality of strategy usage, as well as perceptions of the effectiveness of remote stakeholder engagement. We consider the limitations of students' strategies and perceptions and the gaps between students and practitioners as findings in and of themselves with potential implications for education.

2.5.1 Remote prototyping and engagement strategies

2.5.1.1 Use and adaptation of general strategies for stakeholder engagements with prototypes

Of the 17 general strategies for engaging stakeholders with prototypes described by Rodriguez-Calero et al. (2020), 12 were reported by practitioner participants during remote stakeholder engagements, 7 of which were reported by multiple participants. Table 2.2 includes a list of all 17 strategies from Rodriguez-Calero et al. (2020) and the number of practitioners in our study who described using each prototyping strategy in their remote engagements with stakeholders.

Table 2.2 Number of participants who reported strategies from Rodriguez-Calero et al. (2020)

	Strategy	**Practitioner Count (out of 10)**	**Student Count (out of 10)**
1	Show a single prototype to the stakeholder	10	10*
2	Brief the stakeholder about the project and the prototype(s) shown	7	10*
3	Show the stakeholder multiple prototypes concurrently	6	9*
4	Polish the prototype(s) shown to the stakeholder	6	3
5	Prompt the stakeholder to select prototypes and prototype features	4	9*
6	Show the stakeholder supplemental materials related to the concept to complement the prototype	4	3
7	Have the stakeholder interact with the prototype(s) in a simulated use case	3	0
8	Lessen a prototype's refinement when showing it to the stakeholder	1	1
9	Modify the prototype(s) in real time while engaging the stakeholder	1	1
10	Present a deliberate subset of prototypes to the stakeholder	1	0
11	Observe the stakeholder interacting with the prototype(s)	1	0
12	Encourage the stakeholder to envision use cases while interacting with the prototype(s)	1	1
13	Task the stakeholder with creating or changing the prototype(s)	0	0
14	Reveal only relevant information to the stakeholder specific to the prototype or its use	0	0
15	Introduce the prototype(s) to the stakeholder in the use environment	0	0
16	Standardize the refinement of prototypes shown concurrently to the stakeholder	0	0
17	Make prototype extremes to show the stakeholder	0	0

*Strategies frequently used by students with limited, course-focused strategic design goals

Of the 12 strategies described by Rodriguez-Calero, et al. (2020) that were reported by practitioners in this study, two strategies were described by practitioner participants as being used for different purposes than were described for in-person engagements in prior research. In the case of the strategy "Show the stakeholder supplemental materials related to the concept to complement the prototype," practitioners reported the use of complementary prototypes to elaborate on design details in Rodriguez-Calero et al. (2020). For participants in our study, complementary prototype formats were instead used to compensate for missing tactile feedback and/or in-person facilitation of an engagement by the designer. For example, Practitioner Participant 1 described sending physical mockup prototypes alongside Computer-Aided Design (CAD) models of a new product to potential clients:

> *This combination between [sending] a physical product, which is an 80% representation of the product. and a CAD model which is also kind of an 80% representation because you can't feel how heavy it is and those kinds of things – I think we're able to convey our message better.*

Similarly, the strategy "Polish the prototype(s) shown to the stakeholder" was described as a way to prevent stakeholders from becoming distracted by unfinished details of a prototype (Rodriguez-Calero et al., 2020). In the remote engagements described by participants in our study, the level of refinement of a prototype was sometimes increased to offset a perceived risk of misunderstanding due to remote communication formats. As an example, Practitioner Participant 5 discussed sharing photos and videos of physical prototypes with clients:

> *I'd spend some more time curating how it's presented. So, I spend a lot of time showing how the mechanism works, doing different trials, taking videos, and those are super helpful.*

Student participants reported the use of nine of the strategies defined by Rodriguez-Calero et al. (2020); all of which were also reported by practitioners with the exclusion of "Present a deliberate subset of prototypes to the stakeholder," "Observe the stakeholder interacting with the prototype(s)," and "Encourage the stakeholder to envision use cases while interacting with the prototype(s)." Several of the strategies most frequently used by student participants, indicated by asterisks in Table 2.2, were often used in ways that were tailored towards meeting requirements of their course and limited in scope compared to practitioners' usage. Combinations of the strategies "Show a single prototype to the stakeholder" and "Brief the stakeholder about the project and the prototype(s) shown" were often used in a reporting format to demonstrate progress to project sponsor or instructor stakeholders or request design input in an open-ended way:

> *We would present a CAD model or picture of the physical prototype [to project sponsors]. And the purpose of having those prototypes is, one, to fulfill the requirement of the course, because that's required – we want to report our progress – and second is to get feedback on how we can improve on our solutions. (Student Participant 4)*

Similarly, "Show the stakeholder multiple prototypes concurrently" and "Prompt the stakeholder to select prototypes and prototype features" were often used to prompt stakeholders to help the student teams make design decisions:

> *By showing our current [sketched conceptual prototypes], all of our [project sponsor and instructor stakeholders] realized that it is best just to focus on [one of our design concept options]. (Student Participant 8)*

Outside of these four prototyping and stakeholder engagement strategies (number 1, 2, 3, and 5 in Table 2.2), practitioners participants reported an average of 1.8 additional strategies, each, while student participants reported an average of 0.9 additional strategies.

2.5.1.2 Strategies specific to remote stakeholder engagements with prototypes

Three distinct, previously unreported prototyping strategies for remote stakeholder engagement during front-end design emerged from our analysis. Each strategy is based on a specific way to communicate with stakeholders across distance, while allowing for flexibility in the types of prototypes used and the ways in which stakeholders were asked to interact with the prototypes.

These strategies are described in Table 2.3 with the number of participants who described the strategy and example excerpt from their interview responses.

Table 2.3 Number of participants who reported strategies from Calero-Rodriguez et al. (2020)

Strategy	**Description**	**Practitioner Count (out of 10)**	**Student Count (out of 10)**	**Representative quotations**
Present prototype(s) to the stakeholder through a virtual platform	Share a digital or physical prototype with the stakeholder for an engagement session conducted via a video call.	5	7	*...one of the particular things that helped in this project was that when we're at the early stages of conceptual design was doing some drawings on [an] online platform - it's like AutoCAD. And then sharing the drawings with the rest of the team and also with our clients. (Practitioner Participant 10)*
Send physical prototype(s) to the stakeholder	Allow the stakeholder to interact with the physical prototype with or without guiding questions or instructions, but without the designer physically present.	5	1	*We've developed a process that sort of works [for remote stakeholder engagement] and clients seem to be pretty engaged with getting physical [3D printed] prototypes and things to play with. (Practitioner Participant 3)*
Present prototype(s) to the stakeholder through a third party instead of by a design team member	Facilitate interaction between the stakeholder and prototype through an in-person meeting with a third party who is not a member of the design team.	2	0	*So, for the one project, they'll have the copy because we'll mail [a functional prototype] to their sales rep and then the sales rep will bring the prototypes to [a representative user]. And those two will be in person and we'll be remote [during the engagement]. (Practitioner Participant 4)*

In some cases, participants described these remote strategies as being used before the COVID-19 pandemic and/or in tandem with in-person strategies, while in other cases they described remote strategies as adaptations that were initiated or used more commonly during the pandemic.

2.5.1.3 Practitioner use of concurrent, complementary remote and in-person strategies

While distinct from general prototyping and stakeholder engagement strategies described by Rodriguez-Calero et al. (2020), the remote strategies listed in Table 2.3 were generally reported as complements to, rather than replacements for, other strategies by practitioners. For example, Practitioner Participant 3 described coupling remote strategy "Send physical prototype(s) to the stakeholder" with the strategies resembling "Prompt the stakeholder to select prototypes and prototype features" and "Polish the prototype(s) shown to the stakeholder":

> *We produced some 3D printed prototypes that were painted and sort of 'looks-like' models of just small sections [of the product]. [Clients] weren't present for meetings, so we just shipped them over to them and were like, 'Give us feedback. Which do you prefer?' and gave them a specific list of questions of things we wanted them to answer. That was pretty successful.*

Similarly, elaborating on the excerpt in Table 2.3, Practitioner Participant 4 described using the remote strategy "Present prototype(s) to the stakeholder through a third party instead of a design team member" along with the general strategy "Have the stakeholder interact with the prototype(s) in a simulated use case" in order to maximize the quality of remote engagements:

> *We've been mailing [functional prototypes] to our sales reps and then the sales rep will take the kit and meet with the [representative user]. We set up a video call and we'll watch. We'll have them arrange their camera such that we can watch the [representative user] actually apply the product. And then we have a series of questions to ask.*

As another example, Practitioner Participant 7 described combining the remote strategy "Send the prototype to the stakeholder for asynchronous interaction" with "Task the stakeholder with creating or changing the prototype(s)"

> *[Manufacturing stakeholders] had the physical build with them there. So, if we had to do any design changes, they would actually take me through them on a video call while they were standing with the [functional] prototypes and I was at home.*

Of the three new strategies specific to remote stakeholder engagement with prototypes described by practitioners, two were also described by student participants: "Present prototype(s) to the stakeholder through a virtual platform" and "Send the physical prototype to the stakeholder," while "Present prototype(s) to the stakeholder through a third party instead of a design team member" was not reported.

2.5.1.4 Student competencies in virtual communication

Student participants' discussions of virtual communication strategies in remote engagements demonstrated considerably more depth and intentionality than discussions of remote prototyping and engagement strategies more generally. For example, Student 6 reflected on the nuanced communication advantages of remote engagement strategies:

> *You have a little bit more permanence [with remote engagements]. If you have a drawing and you send it remotely or you're presenting and then you follow up with an email afterwards with that drawing or that CAD file, that's definitely good in terms of the [project sponsor or instructor] being able to refer back to it.*

Similarly, Student Participant 9 provided an example of tailoring the content and mode of communication to a stakeholder's needs in a virtual setting:

> *[I was] more organized about [remote engagements with a project sponsor or instructor]. I'd have a game plan about what information I want to communicate first then figure out the best way of communicating. I think slideshows come up more often when presenting to people outside of my immediate design team just because there's only so much you can talk about in a certain amount of time. So you have to hit every important point at a high enough level that they understand, but not so deep that you have to talk about it for five years.*

In another example, Student Participant 2 described strategic intent in the communication strategy used when presenting virtual prototypes over a video call:

> *With CAD we tried really hard to get nice [rendered images]. We specifically oriented our joint in a certain way and then added other graphics around to help visualize how exactly everything moves in relation to everything else, which I think made a big difference in letting our [project sponsor or instructor] understand exactly what we were talking about. In the middle of the presentation, it's difficult to have actual Solid Works up to rotate so we came up with a couple of methods just to make that process easier [which were tailored to] our specific solution.*

2.5.1.5 Relationships between types of stakeholders, prototypes, and remote engagement strategies

Across our findings, practitioners and students discussed various types of prototypes and stakeholders in relation to remote engagement strategies. While did not aim to assess relationships between individual strategies, stakeholders, and prototypes in detail with the sample size and research methods used in this study, evidence of general trends was visible. Practitioner and student participants reported strategies like "polish the prototype(s) shown to the stakeholder" and the use of higher-fidelity prototypes for non-technical and management stakeholders who were less familiar with the details of a design to reduce miscommunication during remote engagements, as was discussed by Practitioner Participant 3:

> *If it's a more senior stakeholder that is less technical [in a remote engagement] we'll have made sure [the prototype is] more polished to start with, and we'll just give [the non-technical, decision-maker stakeholder] shorter, simpler instructions.*

Similarly, when discussing presentations to a project sponsor, Student Participant 4 described the use of more virtual prototypes for the sake of achieving clear communication:

> *We don't use any [test material prototype] mock-ups when we're [presenting to our project sponsor virtually]. Instead, we use [digital] sketches or 3D models or something similar that is easy to present virtually.*

As another example, Practitioner Participant 2 offered advice on how to adjust prototype fidelity based on the stakeholder in the context of remote engagements:

> *The first thing is understanding who your stakeholder is. If it's somebody that you have good rapport with and understands how you communicate, then you don't need to take that prototype to the same degree of completion as you would if you're communicating with a potential user or with a key decision-making stakeholder like a manager [...]. Remote work exacerbates those problems [related to communicating prototypes to stakeholders].*

2.5.2 Perceptions of remote stakeholder engagement and prototyping

2.5.2.1 Perceived advantages and limitations of remote stakeholder engagement compared to in-person engagements

Practitioner participants reported a range of advantages and limitations of remote stakeholder engagements with prototypes compared to in-person engagements. Discussions related to the effectiveness of remote engagements, the broader impacts of remote engagements on design processes, as well as the quality designers' personal experience or satisfaction in their work. Perceived advantages and limitations are described in detail in Tables 2.4 and 2.5, respectively.

Table 2.4 Practitioner participants' perceived advantages of remote stakeholder engagement with prototypes

Theme	Sub-theme	# of practitioners who reported theme	Representative quotations
Effectiveness of stakeholder engagements	Remote stakeholder engagement can, in some cases, accelerate design processes	3	*Well, I would say remotely you might be able to iterate faster possibly […] reach out to more people at the same time. So, if I would have a digital [CAD prototype], I have a list of people I want to share it with, I just have to change a few things. Just looking at having the physical prototype, we have a few different versions for different clients, but the time which has been invested in making those compared to changing the CAD model […] is significantly more. (Practitioner Participant 1)*
	Remote engagement allows for access to otherwise inaccessible stakeholders	2	*The advantage here is that specifically we're getting that international feedback [from representative users by sharing CAD-generated 2D and 3D images]. We probably wouldn't have gone to all these different countries in person. We would have just gotten US feedback, and the product has different uses in the US versus internationally. So having the chance to do that virtually [due to COVID-19] is allowing us to get a wider range of feedback. (Practitioner Participant 4)*
	Asynchronous remote interaction with prototypes gives stakeholders more time to create informed opinions about prototypes, which is not possible during typical in-person engagements	1	*It gives [clients] a longer period of time to engage with the prototype. So, typically, if it's in-person, they'll have [a functional prototype] for a few minutes in the meeting before you expect answers from them. Whereas remotely, you can send it and they may have it for a few days, and they share it round to all the different people who have views and are stakeholders but maybe wouldn't have got invited to the meeting that we would have been having the discussion in. So, it probably reaches more stakeholders and gives them a longer period of time to actually work out what it is that they like or dislike about it. (Practitioner Participant 3)*
Design process efficiency and effectiveness	Remote stakeholder engagement can, in some cases, allow for more efficient use of time and resources	5	*I personally like it when I'm sitting at the comfort of my home, my desk, getting my coffee, and then thinking about the concept of the prototype, as opposed to being in the office with everyone running different tasks around me, noise level's high. I need to think about: "Okay, I need to get on the train at 5:00 otherwise I'm going to be stuck in this traffic, or miss the next train and arrive 30 minutes later at home." Just reducing those stresses helps a lot with the design or thought process or being focused […] in my opinion. (Practitioner Participant 10)*
	Remote stakeholder engagement encourages more effective planning, communication, and creative problem-solving	5	*[Through remote prototyping I re-focused on] the get it right, 'measure twice, cut once' sort of thing. It forces you to think more about how things are going to come together when you're not the person that's assembling it. I think that probably would be good to apply that in any prototyping setting, regardless of whether or not you're in-person. (Practitioner Participant 2)*

Table 2.5 Practitioner participants' perceived limitations of remote stakeholder engagement with prototypes

Theme	Sub-theme	# of practitioners who reported theme	Representative quotations
Effectiveness of stakeholder engagements	Remote engagements sometimes offer limited physical interaction with prototypes by stakeholders	3	*If it's got tactile feedback or somebody had been asking about, 'How do you think this feels?', that we can't do remotely. (Practitioner Participant 3)*
	Remote engagements require increased planning and preparation	3	*The get it right, measure twice, cut once sort of thing. It forces you to think more about how things are going to come together when you're not the person that's assembling it. (Practitioner Participant 2)*
	Remote engagements offer limited opportunities for designers to guide engagements or for stakeholders to provide feedback	2	*With the feedback that we got on the [functional prototype] where our [representative user] was saying, "This is too much force required," and he just wasn't happy with the performance. We don't know how hard he was actually pressing. Maybe he just wasn't giving it enough force at all and that's why it didn't really [work]. We weren't there in person to see what was happening. All we saw was what he was doing [over a virtual meeting platform] and then his thoughts about it after. So, it would have been easier if, had we been there, to say, "Wait, put a little bit more pressure" or something like that, but that's just something that we'll have to work around. (Practitioner Participant 4)*
Designer experience or efficacy	Remote engagements provide less personal satisfaction for the designer	1	*Nothing replaces the in-person joy of seeing somebody else get how something works – the sort of collective enjoyment over making something work is just not the same remotely. (Practitioner Participant 5)*

Compared to practitioner participants, student participants reported relatively few perceived advantages and disadvantages of remote engagements with prototypes versus in-person. In addition, student participants did not discuss intentionally balancing the advantages and limitations of prototyping strategies for remote stakeholder engagement during front-end design in most of the ways that were described by practitioner participants. Most student participants discussed cases of leveraging remote communication strategies into advantages, however. For example, Student Participant 1 reported that when sharing prototypes on a video call:

I think it's more conducive [when you are] virtual in terms of hearing everybody. I feel like when you're in person it's a lot easier to talk over people. It's a lot easier to interrupt people. Whereas when you're virtual usually one person's talking...

Similarly, Student Participant 2 said that:

I think it's nice that when you're remote – everybody instantly has a computer in front of them [...] so all you have to do is hit share screen on your CAD and [...] everybody's seeing exactly what you're seeing and there's no need to all crowd around one big TV screen.

In both examples, Student Participants demonstrated the ability to take advantage of specific strengths of remote communication formats while engaging stakeholders with prototypes.

2.5.2.2 Perceived impact of remote stakeholder engagement with prototypes on design

While many practitioner participants reported that remote stakeholder engagements during front-end design required more effort or advance preparation, all 10 reported that overall, they felt the use of prototypes during remote stakeholder engagements did not affect the final quality of design outcomes compared to in-person engagements. For example, Practitioner Participant 4 said that:

…in-person versus virtually, we weigh them the same.

Similarly, Practitioner Participant 3 reported:

I think both ways [in-person and remote] get similar responses. Maybe over a different timeline. But in terms of the final outcome, I think it tends to be pretty similar.

Practitioners instead described balancing remote and in-person strategies for stakeholder engagement with prototypes before and during the pandemic. As an example, Practitioner Participant 6 reported:

Remote communication [with stakeholders] before COVID existed because we are a global company, and many of the senior leadership stakeholders reside in other locations and countries. Because of this, the process pre- and post-COVID largely remained the same. The teams go through decision stages early on with digital concepts because you can get broader variation without spending a lot of time fully realizing physical samples. Physical prototypes come later when there is more certainty on the end look and feel. In those cases, leadership would often travel on-site or are sent samples ahead of meetings.

In addition, the transition to increased remote work during the COVID 19 pandemic was discussed as a driver of innovation in remote prototyping and stakeholder engagement strategies. Multiple practitioners described finding new, low resource means of prototyping and engaging with stakeholders while working from home that were effective but would not have been considered before the pandemic. It should be noted that even in cases where strategies were developed ad-hoc during the pandemic, practitioner participants did not describe negative impacts on the overall quality of their work. For example, Practitioner Participant 5 reported two positive changes to remote prototyping and engagement processes because of the pandemic:

[As a result of the pandemic, we] might end up including clients in more brainstorms, even if they're not located closely. I think there's a lot of value, in particular, in that. And even though they're a little bit painful in terms of the extra amount of work that goes into kind of coordinating all the results, there's so much value that they will bring to the table that you just don't get otherwise.

In terms of mocking things up [the shift to remote design work] has been kind of just a reminder of just how fast you can do things with common objects around your house.

Student participants reported mixed perceptions of the impact of remote stakeholder engagements with prototypes on design process quality. Unlike practitioner participants, all 10 of whom reported that remote stakeholder engagement with prototypes need not ultimately affect the quality of design outcomes, six students reported that the overall impact of remote engagements was not detrimental to their design work, while four said that it was detrimental. In addition, several student participants described the remote nature of their stakeholder engagements as challenging in ways that practitioners did not. For example, Student Participant 9 said:

> *But the in-person portion is really nice, because if you're running into an issue, sometimes over virtual it's really hard to communicate that [to instructors]. So, it can be really isolating. There's a lot of problem solving on your own...*

2.6 Discussion

2.6.1 Usage of strategies for remote stakeholder engagement with prototypes

The use of 12 of the 17 strategies from prior research on general engagement with prototypes in front-end design (Rodriguez-Calero et al., 2020) by practitioner participants in remote contexts indicates some transferability to remote design. In addition, the limited number of strategies from prior research that were clearly modified in remote contexts (two) supports transferability of strategies between in-person and remote design. The relatively small number of unique strategies that emerged for remote engagements with prototypes in front-end design (three) may provide additional evidence that most remote strategies overlap with previously described strategies, rather than being completely unique to remote contexts. Similarly, the fluid way in which practitioners discussed remote, in-person, and hybrid stakeholder engagements strategies supports the transferability of strategies across remote and in-person contexts. This flexibility aligns with the findings of Coulentianos et al. (2020a) in a related study of prototyping strategies for stakeholder engagement in international design contexts, where designers were found to balance in-person and remote communication, among other factors, to collect stakeholder input effectively.

The absence of the remaining five strategies described in Rodriguez-Calero et al. (2020) as well as the low prevalence of several other strategies, has several potential explanations. Some strategies, such as "Task the stakeholder with creating or changing the prototype(s)" or "Introduce the prototype(s) to the stakeholder in the use environment" may be less feasible or effective in a remote engagement, as there is likely to be less opportunity to observe stakeholders in as much detail or maintain necessary guidance on the stakeholder's behavior. This explanation is in-line with a report (Lund, 2020) on the efficacy of remote work by type of task, which found that while most work in fields like engineering can be done remotely, "communicating with and guiding colleagues or clients" is among the most challenging tasks to carry out remotely. Other explanations for the absence of some strategies include the limited number of designers and design industries sampled in this study; different individuals, organizations, and industries may have different approaches that were not captured in this research.

In addition, the 17 strategies described in prior work sometimes mapped to those reported by practitioners and students in overlapping or ambiguous ways. For example, the case described in section 4.1.3 where Participant 3 reported showing a stakeholder only certain components of a product could reasonably be interpreted as presenting a deliberate subset of prototypes (strategy 10), prompting the stakeholder to select prototypes and prototype features (strategy 5), or both. This excerpt also includes strategy 3: showing the stakeholder multiple prototypes concurrently, which along with strategy 1: showing a single prototype, could apply to most engagement cases alongside other strategies. This ambiguity implies that 1) designers may often have multiple objectives and employ multiple strategies when using prototypes to engage with stakeholders, and 2) there are likely to be opportunities to further categorize and develop the 17 strategies in ways that improve their clarity and usefulness in structuring stakeholder engagements.

Regarding the three remote prototyping strategies for stakeholder engagement in front-end design that were not described explicitly by prior literature, the communication modes described: virtual communication platforms, physical prototypes sent to the stakeholder, and the use of an intermediary engagement facilitator as a stand-in for the designer appear to broadly cover the types of remote engagement modes available to a designer. There is likely room for further expansion or subdivision of these strategies through future research, however. For example, there was some evidence of the intentional use of either synchronous or asynchronous engagement strategies when digital or physical prototypes were sent to stakeholders, but it is not clear from our data whether and how these events might be described as independent prototyping strategies for stakeholder engagement.

Overall, student participants reported fewer strategies per participant than practitioners (roughly half as many when strategies that were used in limited ways to meet instructor and project sponsor expectations are excluded). This gap between practitioner and student participants exceeded our expectations, and may be because of the limitation of a course-based design environment, the change to a remote course format due to the pandemic and/or limited opportunities for in-person stakeholder engagement, or because student participants were not aware of the range of prototyping and stakeholder engagement strategies available to them due to limits of prior design experience and/or education. It is worth noting that student participants' strategies often appeared to be effective in the context of meeting the requirements of their course, but were not representative of the level of stakeholder feedback collected by practitioners with nominally similar prototyping and engagement strategies. This may highlight limitations of the project-based design course in replicating professional design practice. While it is not possible to fully determine the reasons for the difference in perceptions between practitioner and student participants in our data, nor the extent to which the pandemic may have influenced the lower number of strategies reported by student participants, this finding may still indicate a gap between engineering design education and professional practice worth considering for targeted educational interventions.

Despite student participants' comparatively limited usage and perceptions of stakeholder engagement strategies, they appeared to be more effective in the use of digital prototyping and communication tools. Student participants demonstrated greater consideration and intentionality with digital prototypes and communication tools than with stakeholder engagement and prototyping strategies in general. This is not to say that student participants necessarily matched or exceeded the skills of practitioner participants in these areas, as these skills me be implicit and commonplace in professional work and therefore were not discussed by practitioners during interviews, but our data did not show a clear disparity between student and practitioner participants in digital communication and prototyping skills. Student participants have grown up using digital technologies, including those related to CAD software and video communication platforms. As a result, students may be likely to apply these skills to problems in ways that may not be as intuitive to older engineers, as is supported by a study of problem-solving abilities of recent generations of students (Ting, 2015). Student participants' digital literacy may also have been demonstrated by their awareness of the limitations of virtual communication formats and the related risk of miscommunication with non-technical stakeholders, which was mitigated by the intentional use of higher-fidelity prototypes – a strategy which was shared by practitioners. It should also be noted that while not the focus of this study, participants sometimes talked about prototyping strategies for remote stakeholder engagement in ways that overlapped with the back-end of design. This overlap is in line with findings from Lauff et al. (2020), which described the use of prototypes in later design stages to persuade stakeholders to agree with a design direction or to collect stakeholder feedback to validate designs. Our results, as well as the cross-over in participants' discussion of front- and back-end strategies during this research, suggest that there may be meaningful overlap across front-end and back-end design within the prototyping strategies for stakeholder engagement described in this work and others, which could be explored in future research.

2.6.2 Intentionality of Strategy Usage

Our findings demonstrate that engineering design practitioners' strategies for prototype usage during remote stakeholder engagements in front-end design were often intentionally tailored to suit specific design needs. This intentional use of strategies is consistent with other literature describing prototyping and stakeholder engagement strategies in general as applied intentionally for a given context during front-end design (Camburn et al., 2017), as well as literature specifically describing the use of prototyping strategies for stakeholder engagement during front-end design (e.g., Coulentianos et al., 2022; Coulentianos et al., 2020a, 2020b; Rodriguez-Calero et al., 2020). Significantly, practitioners discussed in-person, remote, and hybrid engagement practices as having unique advantages and limitations, which they leveraged strategically to meet specific design needs.

In the case of student participants, it seems likely that the presence and/or prevalence of some strategies reported were artifacts of the course requirements more than a representation of student participants' skills, indicating reduced intentionality in selecting strategies. In particular "Prompt the stakeholder to select prototypes and prototype features" appears to have been a likely derivative of a course requirement that student participants develop three independent design concepts before narrowing down to one, typically with input from other project stakeholders. Student participants appeared to ask stakeholders to make design decisions for them rather than approaching engagements with strategic intent to elicit stakeholder perceptions in order to support their own decision-making. This finding indicates another possible limitation of the course-based design experience studied, as well as opportunities for changes to course structures to bring students' stakeholder engagement experiences closer to what may be experienced in professional work and/or other forms of support for prototyping and stakeholder engagement skills, as has been called for in prior research (e.g., Deininger et al., 2017, 2019; Viswanathan et al., 2014).

2.6.3 Perceptions of remote stakeholder engagement with prototypes

While limitations to remote prototyping and communication strategies were reported, in some cases limitations were described as being overcome or converted to advantages, such as when increased and easier access to more stakeholders through digital communication offered new or more effective design opportunities, as has been described in previous research on remote design work (Li & Qiu, 2006). In other cases, the limitations of remote engagements were described as a worthwhile trade-off for the higher financial cost of in-person engagements, which would have included higher travel or shipping costs, communication delays, or staff time. Practitioners, who reported frequent combinations of in-person and remote stakeholder engagements with prototypes for projects, evaluated the costs and benefits of each modality of engagement when developing stakeholder engagement plans.

Compared to practitioner participants, student participants demonstrated fewer prototyping strategies for stakeholder engagement during front-end design, and perceived remote engagements as being more difficult and time consuming than in-person engagements, as well as less effective. While student participants had limited in-person engagement experience as a point of reference, these results may still imply that students may benefit from additional scaffolding as they learn prototyping strategies for stakeholder engagement during front-end design when engaging remotely. With these gaps in students' understanding in mind, we propose recommendations for educators to support the development of relevant skills:

1. Reinforcing the value of strategic intent in developing prototyping and stakeholder engagement plans
2. Providing specific prototyping strategies for stakeholder engagement across in-person and remote formats
3. Communicating the value and prevalence of remote and hybrid work in industry, along with general strategies to overcome challenges or leverage challenges into advantages
4. Providing practical exposure to projects with elements of remote stakeholder engagement

These recommendations overlap with calls for explicit, advance preparation of engineering students to perform often unfamiliar remote work effectively by Asadi, et al. (2017), and calls to support students in overcoming low motivation due to the added challenges of remote design projects by Utriainen et al. (2017). In addition, we propose that students' relative expertise with digital communication formats may be leveraged in remote design skills training. Connecting students' pre-existing knowledge of the advantages and limitations of digital communication tools to the intentional, strategic design of stakeholder engagement plans may help them overcome the challenges reported in this research and described by Utriainen et al. (2017).

2.6.4 Limitations and recommendations for future research

This work is a starting point for the exploration of remote stakeholder engagement with prototypes in engineering design but, as discussed above, our sample size did not allow us to discern possible differences between industries or relationships between types of stakeholders, prototypes, and engagement strategies. Larger sample sizes and the inclusion of participants from additional design industries would likely be needed to address these questions and to potentially identify additional engagement strategies. In addition, this study was not designed to assess the quality or effectiveness of strategies, which could be explored in future work. As our data collection was limited to a single mode due to the pandemic (interviews over a video call platform), observational or other research methods could also be used to expand this research, as well as to isolate front-end design activities by collecting data during the front-end of design projects rather than through reflective interviews that may take place after all design stages are complete. Controlled experiments could also be designed to study specific strategies and perceptions of students and/or practitioners in more detail. Additional study of remote engagement strategies in design cases not shaped by the transition to remote work and education during the COVID-19 pandemic may also illustrate alternate or complementary practices.

In addition, the division between front-end and back-end design was sometimes unclear in the data collected, potentially limiting the accuracy of counts of the numbers of participants who reported each strategy. Though we expect some level of transferability between the strategies and perceptions described for the design front-end in this research to later design stages, future research could explicitly explore remote prototyping and stakeholder engagement in back-end design or across design stages to further develop knowledge of prototyping and engagement strategies, as well as to clarify similarities and differences between design stages. Future work is also needed to differentiate between strategies focused on prototypes, communication formats, stakeholder interaction design, etc., within prototyping strategies for stakeholder engagement, which are not characterized individually in this study. More work is needed to develop and test pedagogical material/tools to teach engineering students how to conduct remote engagements effectively, as well. Finally, since this study was conducted as organizations and universities were adjusting to COVID-19 restrictions, additional work is needed to assess the strategies of practitioners and students during more typical design experiences, and to compare our findings to pre- and post-pandemic practices.

2.7 Conclusion

The outcomes of this work support the field of engineering design in its response to the need for remote stakeholder engagements due to ongoing trends towards globalized, distributed design work, which have been accelerated by the COVID-19 pandemic. The usage of prototyping strategies for remote stakeholder engagements in front-end design was described. Most strategies were found to overlap with strategies described by prior literature that are not specific to remote engagement modes, though several of these strategies were adapted to serve different purposes in the remote context. In addition, three distinct strategies for prototyping in remote engagements were defined, which included the use of virtual communication formats, physical prototypes sent to remote stakeholders, and third-party engagement facilitators standing in for a remotely located designer.

Designers' perceptions of the value and effectiveness of remote versus in-person prototyping strategies for stakeholder engagements were also summarized. The main findings from practitioner participants indicated that (1) while remote engagements may require more effort, advance preparation, and strategic communication, the quality of engagement results and design outcomes can be the same as from in-person engagements, (2) remote engagement allows access to stakeholders who might not otherwise be available to the designer, and (3) that even in primarily in-person work environments, prototyping strategies for remote engagement may add value and should be considered alongside in-person engagement when stakeholder engagement plans are developed.

Finally, practitioner participants' more nuanced understanding of remote engagements compared to student participants highlighted several recommendations for educators to better prepare engineering students for the hybrid and remote work they are likely to face as practitioners. These recommendations include (1) reinforcing the importance of strategic intent in developing prototyping and stakeholder engagement plans, (2) providing specific strategies for prototypes and stakeholder engagements across in-person and remote formats, (3) emphasizing the value and prevalence of remote and hybrid work in industry, along with general strategies to leverage opportunities and overcome challenges related to remote work, and (4) providing practical exposure to projects with elements of remote stakeholder engagement.

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Chapter 3 Exploring Engineering Student Perspectives on Positionality in Design for 'Social Good' Collaborations[2]

3.1 Abstract

Collaborations within engineering student teams and between 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 a designer's own positionality, which can be defined as the ways a designer's identities affect their social and political position relative to stakeholders in a given 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 between 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 design work is lacking. As a starting point for the exploration of the role of positionality in design, this research characterized the ways student designers conceptualized their positionality 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

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findings included 1) connections between participants' own minority identities, related life experiences, and conception of positionality in 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 design education strategies to improve the consideration of positionality for students engaged in design for social good projects, with implications for stakeholder engagement and partnership-building skill sets.

3.2 Introduction

Engineering programs and experiential learning opportunities that emphasize positive social impact are increasingly in demand (Smith et al., 2020). Often described with terms like humanitarian, sustainable, social justice, etc., we call these sociotechnical learning experiences collectively "design for social good" for the purposes of this research. In design for social good work, differences in identities between designers and other stakeholders are especially common and typically feature situations where designers hold privileged identities compared to other stakeholders. This makes it especially critical for a designer to consider their positionality, which is defined as the ways an individual's identities affect their social and political position in a given context (Alcoff, 1988). This also makes design for social good a natural starting place for the exploration of the roles of positionality in design. In the context of engineering design, positionality may influence how a designer seeks out and interprets information, as well as how a designer 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 between themselves and other stakeholders, nor understand how personal values and biases influence design decisions.

This may lead to ineffective collaborations within teams and between designers and other stakeholders, ultimately affecting the outcomes of design solutions.

Positionality affects decisions throughout a design process, including during its earliest stages, where problems are defined, requirements are specified, and initial ideas are proposed (Morgan et al., 2020). The lack of consideration of positionality limits the effectiveness of student design approaches and collaborative relationships (Fox et al., 2020), often leading to project failures (Mazzurco & Jesiek, 2014; Nieusma & Riley, 2010). Moreover, inadequate design approaches in these cases not only waste resources but may reinforce inequities (Leydens & Lucena, 2018). Design programs often consider the reflective skills needed to address concepts like positionality in a limited way, if at all (Cech, 2013; Loweth et al., 2020; Lousberg et al., 2020; Sienko et al., 2018), and the literature lacks discussion of training on positionality (Walji et al., 2020). In addition, empirically based pedagogy on the consideration of positionality in design work is lacking. Further, from a research perspective, the ways in which designers consider or neglect positionality in developing design approaches have not been thoroughly explored (Walji et al., 2020). 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. As a starting point for 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.

3.3 Background

3.3.1 Identity, Positionality, and the Role of Positionality in Engineering Design

An individual's positionality, defined as how their identities affect their social and political positions (Morgan et al., 2020) fundamentally influences how -- and how well -- a design process is implemented (Fox et al., 2020; Walji et al., 2020). There are several key characteristics of positionality that may shape interactions in design. Positionality can be thought of as relational, in that the positionality of an individual towards others changes depending on how they relate to the identities of the people or types of ideas they interact with (Alcoff, 1988; Milner, 2007; Secules, 2021). Positionality is also contextual as it is shaped by the circumstances and environment surrounding interactions (Milner, 2007; Secules, 2021). In addition, positionality is intersectional in that the various individual identities that shape it are more than the sum of their parts and may interact to form unique dynamics (Secules, 2021) that affect stakeholders, designers, or their design work. Positionalities are also complex and often complicated (Merriam et al., 2001), as 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 (Alcoff, 2005), and positionalities are often difficult to explicitly name, understand, and account for (Merriam et al., 2001).

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 (Alcoff, 1988). Myriad types of identities contribute to positionality, including commonly considered categories like race, ethnicity, gender, sex, and age, but also include myriad other categories like national origin, political affiliation, personality traits, education, professional experience, etc. (Chou, 2020; Jacobson & Mustafa, 2019; Liu & Hinds, 2012; Tien, 2019), each of which may be more or less relevant to shaping positionality in a given context. Moreover, an identity may be conceptualized 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 (Deschamps & Devos, 1998).

In engineering design, it is often incorrectly assumed that an engineer's good intentions are enough to make up for gaps in their understanding (Leydens & Lucena, 2017). 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 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 (Burleson et al., 2020; 2023), as well as power dynamics between themselves and other stakeholders in design work, both of which are dependent on a designers' positionality (Fox et al., 2020). Similarly, biased or uninformed attitudes and perspectives towards the stakeholders and contextual factors connected to a designer's work, which can arise from a poor understanding of positionality, have been shown to negatively influence interpersonal interactions between designers and stakeholders (Morgan et al., 2020). In addition, reflection is required for an engineer to effectively account for the potential roles of their identities and personal motivations (Chou, 2020), as well their assumptions, values, and biases (Walji et al, 2020) in their design approaches and stakeholder relationships. This reflection may form a feedback loop where an engineering designer actively changes their position or attitude towards design contexts, stakeholders, and themselves as their awareness of their own positionality changes. Figure 1.1 summarizes the ways that positionality comes into play in design, as described above. The lens in the center of the figure may be seen as the positionality of the designer, but could also be applied to other stakeholders who may influence design approaches.

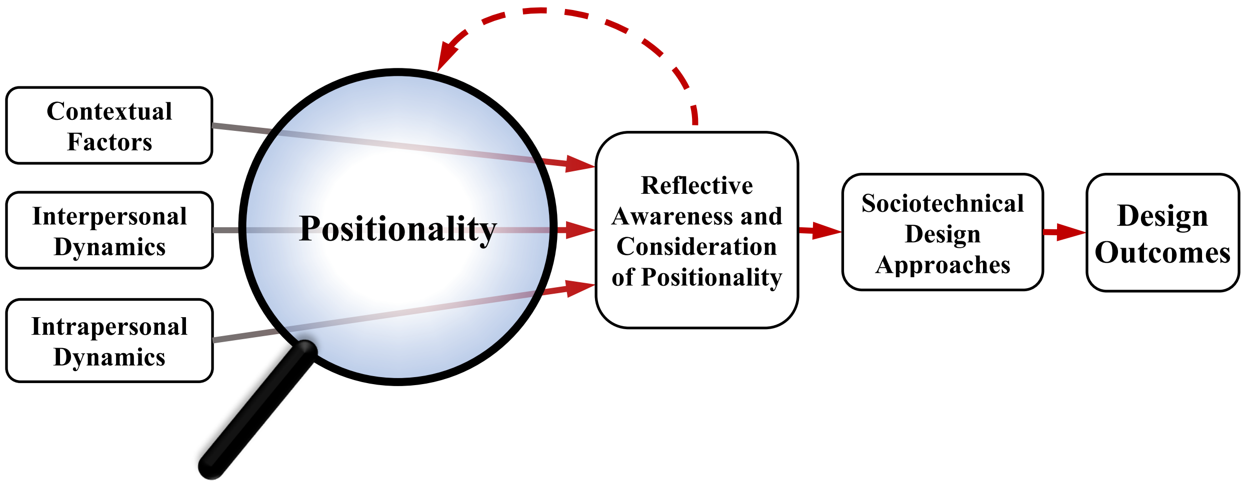

Figure 3.1 Reflective consideration and awareness of positionality in engineering design

Despite the importance of positionality in an engineer's 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 (Passow & Passow, 2017). This culture of depoliticization in engineering communities separates and devalues social or non-technical elements from technical elements of design work, creating a false sense of technical/social dualism and discouraging critical assessment of social structures and norms (Cech, 2013). As a result, student engagement with social welfare has actually been shown to decline over the course of an engineering education (Cech, 2014).

There are many cases describing the consequences of neglecting the role of positionality in professional and student design for social good practice, even though identity and positionality are not always explicitly named. One example included the design of backdoor wheelchair access ramps in the US that enabled entry, but separated users from others who could walk through the front door of the same building (Nieusma, 2004). Another case described an international development project where, 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 designers, onto local contexts and partners in

Nicaragua, again resulting in project failure (Nieusma & Riley, 2010). While current literature describes multiple ways in which positionality is important in design, few studies explicitly study identity or positionality, and no studies consider all the different ways that positionality may come into play, as shown in Figure 1.1. How all these factors come together to influence design and designers, as well as how different designers conceptualize and integrate concepts related to positionality into their work, are not known.

3.3.2 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) (King & Baxter Magolda, 2005), which names specific attitudes and behaviors that represent initial, intermediate, and mature levels of development in conceptions of cultural differences. In the DMIM, culture is connected to categories like national, regional, and ethnic identity differences. It should be noted that according to the Oxford English dictionary, culture may be defined more broadly as "the customs, arts, social institutions, and achievements of a particular nation, people, or other social group," however, so the DMIM may reasonably be applied to a broader range of identities that shape social groups.

Examples of immature conceptions of culture described by the DMIM include assuming unfamiliar perspectives are wrong or having limited awareness of personal values and other 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 identity. 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 with respect to self-authorship has been characterized as 1) circular or iterative as opposed to linear, and that 2) it tends to facilitate stronger interpersonal relationships, rather than hinder them as people develop differently over time (Magolda, 2008).

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 (Fayolle A, Gailly, 2015) and global leadership (Caligiuri P, Tarique, 2009) 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.

3.4 Methods

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

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

3.4.1 Participants

Five participants were recruited from socially focused, co-curricular design programs at the University of Michigan. General participant demographic details are listed in Table 3.1.

Table 3.1 Participant demographics

Participant	Gender	Year in Engr. 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

Additional participant demographics were as follows:

- Four of the five participants were non-white or of mixed race/ethnicity
- Two 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 identified as LGBTQ
- All 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.

3.4.2 Data Collection

Each participant engaged in a written reflection activity, followed by a semi-structured interview, over a video call with the researcher. Both the written activity and interview together lasted for approximately one hour. 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. An overview of the types of information presented to participants is provided 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., Alcoff, 2005; Burleson et al., 2020; Merriam et al., 2001; Nieusma & Riley, 2010)
- A list of 21 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, socially-focused 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 definitions while writing, if desired. Written responses were then used to ground questions in a subsequent interview that prompted participants to explore how their various identities 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 amongst identity, stakeholders, and problem context (Burleson et al., 2020; Deardorff, 2011; Nieusma & Riley, 2010; Parkinson, 2009; Social Identity Wheel, 2022), the DMIM (King & Baxter Magolda, 2005), which has been shown to be an effective framework for interview instruments in higher education (Baxter Magolda et al., 2010; Deardorf, 2011; Soria & Troisi, 2014), and 3) critical theories related to intersectionality and systemic inequality based on identity (Crenshaw, 2013; Ladson-Billings 2009), which have been used effectively in critical, qualitative designer identity research (Dietz et al., 2019). 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 are listed below:

- 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 a designer?
  - 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 a designer today, whether it was positive, negative, or neutral?
  - In what ways was participating in this research surprising to you, if any?

3.4.3 Analysis

Interview recordings were transcribed and de-identified, then data were analyzed deductively to compare student conceptions to those described in literature related to the role of positionality in design, as well as inductively to characterize ways designers relate to positionality that have not been captured by prior research. A deductive codebook was developed from literature (Burleson et al., 2020; Deardorff, 2011; Nieusma & Riley, 2010; Parkinson, 2009; Social Identity Wheel, 2022) to identify similarities between participant conceptions of positionality and published descriptions of the ways that identity and positionality relate to 1) the assessment of contextual factors, 2) interpersonal factors, and 3) intrapersonal factors. Inductive analysis, which is described by Creswell & Creswell (2017) as the development of emergent patterns of meaning as opposed to the assignment of predetermined codes or themes, was applied to the data in parallel to identify themes not explicitly discussed in existing literature. Themes were identified iteratively, as is suggested by Patton (2014) to allow for an understanding of the data to develop as transcripts were evaluated multiple times. Codes broadly related to positionality were developed and assigned to relevant excerpts in the data. These excerpts were then organized into the themes discussed in our findings.

We did not attempt to evaluate the overall maturity or quality of participants' design approaches or outcomes, but instead to clearly characterize students' perspectives with respect to theory and published conceptions of identity and positionality. Similarly, we did not always attempt to distinguish between cognitive, intrapersonal, interpersonal domains of participants' conceptions, as cognitive reactions are not necessarily measurable with the interview protocol we used, and it was not always practical or value-added to interpret intrapersonal versus interpersonal attitudes and behaviors with respect to our research questions.

3.4.4 Researcher Positionality

All authors have experience working with socially focused design research and education efforts. The first author also has experience as a student and professional with engineering design and manufacturing in the US and internationally, primarily for socially focused organizations.

Therefore, our team has first-hand experience with how designers 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, however. All authors are white, Western, and cisgender, and do not share many of the minoritized identities of the self-selected group of student participants in this research. Additionally, the authors do 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 much 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 necessarily 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 is an exhaustive insight into students' perceptions. Instead, with our collective experience and positionalities in mind, we seek to provide a useful characterization of student perspectives that may support the development of inclusive design education and future research on positionality in design, including research conducted by teams with complementary identities and expertise to our own.

3.5 Findings

Findings are divided into 1) participant conceptions related to positionality in design and 2) changes in conceptions related to the reflective positionality activity and debrief.

3.5.1 Participant Conceptions of Positionality in Design

Participants exhibited a range of conceptions related to positionality, from reporting stereotyped views of their own and others' identities and resulting positionalities in design contexts, to describing the consideration of positionality as a key part of their approach in design work. Participants demonstrated evidence of shaping design approaches and interpreting results with the consideration of differences in identity in mind, as well as described cases where potentially meaningful effects of positionality and differences in perspective were ignored. Examples of the ways participants discussed positionality, and the types of stakeholders, identities, or design context they referenced are discussed 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 in 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 [another 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 went on to explain 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 are made out of selfishness.

In addition, while Participant A recognized the negative impact of her team members' failure to account for their positionality, 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 awareness of positionality - especially others' positionality towards them as a designer:

…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 have fair skin. 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 went on to detail 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] 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 went on to describe the importance of gender identity in positionalities towards 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 in stakeholder engagement in design. Some participants also shared cases where 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 come into play at any point while working on a design project Participant C responded with a potential unwillingness or 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 going on 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 rejecting feedback from a subset of potential users outright rather than through a systematic design process, and instead of 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].

3.5.2 Participant Changes in Conceptions Related to Participation in this Research

Participants reported a range of changes in their conceptions of positionality in design as a result of participating in this research study. For example, when asked if any part of participating in the research 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 socially focused work, describing a positive overall experience:

> *I actually really liked it. It just made me think a bit more about [my design project] in a new way […] I'd always known that I was like 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 kind of just like mentally like noting which one like what I thought of in my own personal life.*

Despite a hesitance to acknowledge positionality when discussing her design project work, Participant C described possible reflections on revising her positionality towards her design team members with different disciplinary identities:

> *[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.

3.6 Discussion

3.6.1 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. For example, Participant D's more conceptions of sexuality and race/ethnicity related to their personal experiences 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 socially engaged design, the limitations of design for social good 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. This is not to say that students with certain identities are likely to hold a certain level of maturity with respect to positionality, or that students with a certain understanding of positionality are necessarily prepared to design a certain level or to solve real social problems, but it is clear that the consideration of positionality in design is connected to personal experiences with positionality, specifically through exposure to different identities and contexts. In addition, many conceptions reported by participants were related to identity differences and interpersonal dynamics within teams, as well. It seems likely that students have more experience with positionality in the context of a design team rather than with other stakeholders, in relation to contextual factors, or in terms of reflection on their own biases and values.

There are many possible complications in the characterization of students' concepts of positionality in design, as well, which may factor into the findings in this study. There may be effects related to overconfidence comparable to the Dunning-Krueger effect (Dunning, 2011), where after an initial experience with differences in identities, such as an international project trip, students underestimate the amount of remaining, context-specific learning required to navigate positionality in design. It may also be that students who have more experience with diversity, such as the students in our sample, are not encouraged to grow further if they are surrounded by students with less mature conceptions of positionality. In addition, participants likely had an idea of what the interviewer expected to hear in this study. We acknowledge in some cases, such as when participants described concepts related to positionality in general terms, only, responses may be partially or entirely performative rather than representative the conceptions of positionality the participant would operationalize in a design project.

3.6.2 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 positive, though we also acknowledge that students who may have been less open to these activities would have been less likely to participate in the study. As multiple participants described new awareness of categories of identities, it seems likely that many students do not regularly conceptualize the full breadth of possible types of identities that they and others may hold. Engineering students are likely to have encountered identities on demographics forms and through common labels 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, or other categories in the same way, even though these categories may also influence positionality in design.

3.6.3 Limitations

The lack of inclusion of participants with majority identities limits the range of perspectives included in this work. Students who have less experience with difference may be less equipped to consider concepts related to positionality in their work. 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 expansions to this 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 and across design stages.

3.6.4 Implications

These findings may support the development of design education strategies to improve students' awareness and consideration of positionality in their design for social good projects and design work more broadly, with implications for team dynamics, stakeholder engagement, and partnership-building skill sets. As with other research on engineering student engagement with different cultures (Sánchez-Parkinson et al., 2023) and identities (Fox et al., 2020; Walji et al., 2020), our findings showed 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 connected with the unrecognized personal biases displayed by some participants. Therefore, we propose that engineering educators should support students' opportunities to interact across differences in identities and context, as has been promoted by ABET (2023) and multiple studies related to design for social good (Leydens & Lucena, 2018; Loweth et al., 2020) 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.

While the self-selection of students with one or more minority identities within engineering communities for participation in this research may be seen as a limitation, it may also be seen as a finding in and of itself. All participants described being confronted with often intersectional impacts of positionality due to their identities in educational and personal experiences during and beyond their design for social good project work. These first-hand experiences with differences in identity may further support the claim that exposure to difference is related to conceptions of positionality in design.

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 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 previously. It seems likely that participants' conceptions of positionality in design had not previously been challenged in 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 here could be used 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 (Burleson et al., 2020) and empathy (Lunn et al., 2022). While many questions remain as to what the most effective training tools and methods for preparing students to account for positionality in design, it is clear that the preliminary training activities used prompted some level of new reflections in most participants, and may offer a worthwhile improvement over the absence of explicit consideration of positionality in many design programs and projects.

3.7 Conclusion

In summary, this preliminary study of student conceptions of positionality in design found that student conceptions are developed from personal experiences with differences in identities and contexts. Many of these experiences were from outside of formal education, and students holding 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 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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Chapter 4 How Conceptions of Identity and Positionality Influence Engineering Design for Social Good: Insights from Practitioners and Students

4.1 Abstract

Engineering design applications that emphasize positive societal impacts are growing in popularity. Engineering practice and training approaches typically neglect the critical importance of engineering designers' and other stakeholders' positionalities, however, or how identities impact societal positions in relation to other stakeholders in a given design context. If insufficient attention is paid to positionality, engineers may fail to understand and account for broad problem contexts, diverse viewpoints, power dynamics between themselves and stakeholders, and how their own values and prejudices can influence their design choices, ultimately impacting the effectiveness of their design solutions. Furthermore, there is a lack of research-based training on the incorporation positionality in design work. This study explores the role of positionality in design by examining how 10 engineering students and 10 practitioners conceptualize positionality in the initial stages of design for "social good" projects, where large differences between stakeholder identities are likely to be encountered. Participants completed a written reflection activity, then participated in a semi-structured interview. Key findings across participants include support for the importance of positionality in design processes, particularly in the initial stages, despite its difficult comprehension and the absence of uniform, clear language in engineering communities. Exposure to different identities and contexts was also cited as enabling the development of understanding of positionality in design. These insights

highlight the limitations of positivistic engineering programs and cultures, emphasizing the need for strategic, intentional consideration of positionality in design practice and education.

4.2 Introduction

Engineering design that emphasizes positive social impact is increasingly popular (Smith et al., 2020). Often described as humanitarian, sustainable, design for justice, etc., we call these sociotechnical approaches "design for social good" for the purposes of this study. In design for social good, differences in identities between engineering designers and other stakeholders are common and typically feature dynamics where other stakeholders have minoritized identities compared to more privileged engineers. As a result, it is especially important for an engineering designer to consider positionality in their work. Defined as the ways an individual's identities affect their social and political position in a given context (Alcoff, 1988), positionality influences and/or biases how an engineer perceives the world around them. Similarly, design for social good is a natural subject for the exploration of the implications of positionality in design work, where positionality may influence the collection and interpretation of relevant information, as well as the ways an engineering designer considers or uses their own power and privilege in decision-making. Without adequate consideration of positionality, engineers cannot fully recognize and understand broader design problem contexts, all stakeholder perspectives, power dynamics in design teams or between engineers and other stakeholders, nor can engineers account for the impact of personal values and biases on design decisions. Oversights related to positionality may lead to ineffective design processes and relationships, ultimately harming the quality of design outcomes (Fox et al., 2020).

Positionality affects decision-making throughout a design process, especially during the early stages where problem spaces are explored and defined, design requirements are specified, and initial solution concepts are proposed (Morgan et al., 2020), and inadequate consideration of positionality often leads to project failures in design for 'social good' (Mazzurco & Jesiek, 2014; Nieusma & Riley, 2010). In addition, ineffective design in these cases may not only waste resources but can also reinforce social inequities (Leydens & Lucena, 2018). Design training often considers reflective skills required to develop an understanding of concepts like positionality in limited ways, or not at all (Cech, 2013; Loweth et al., 2020; Lousberg et al., 2020; Sienko et al., 2018), and engineering literature lacks discussion of positionality or training on the implications of positionality in design (Walji et al., 2020). Specifically, the ways in which engineering designers conceptualize positionality in design processes have not been thoroughly explored in research (Walji et al., 2020). Considering these gaps, characterization of engineering designers' awareness and consideration of positionality in their design approaches is necessary to connect positionality to more traditional design skills and the application of technical engineering science. To support the exploration of the implications of positionality in engineering design, this study characterized practitioner and student engineers' conceptions, with an emphasis on the early stages of design for social good work.

4.3 Background

4.3.1 Identity, Positionality, and the Role of Positionality in Engineering Design

Positionality, or the ways in which an individual's unique identities influence their social and political stances (Morgan et al., 2020), is fundamental in the planning and execution of a design process (Fox et al., 2020; Walji et al., 2020), and shapes engineering design activities in several key ways. Research has described common difficulties in clearly defining, comprehending, and accounting for positionalities (Merriam et al., 2001), but characterizes common features of that may help us understand and unpack positionality in a given context. For example, positionality can be characterized as relational, in that the positionality of an individual depends on attitudes towards the identities of individuals they engage with (Alcoff, 1988; Milner, 2007; Secules, 2021). Positionality is also contextual and changes in different conditions or environments (Milner, 2007; Secules, 2021). Furthermore, positionality is intersectional, as an individual's overall identity and positionalities create unique dynamics and are not the same as the sum of the individual parts (Secules, 2021). This intersectionality is not likely to be neutral, as intersectional identities often perpetuate existing privilege or marginalization (Secules, 2021). In addition, positionality is complex and complicated (Merriam et al., 2001), given the many types of identities held by an individual, as well as the similar or different identities that might be attributed to an individual by others (Alcoff, 2005).

Positionality differs from identity in that positionality is not assigned to or by an individual, but instead depends on interactions between individuals (Alcoff, 1988), and is therefore more dynamic. Many types of identities contribute to positionality, including commonly conceptualized categories like race, ethnicity, gender, sex, and age, but also myriad other categories such as national origin, political affiliation, personality traits, education, professional experience, etc. (Chou, 2020; Jacobson & Mustafa, 2019; Liu & Hinds, 2012; Tien, 2019), each of which may be relevant to an individual's positionality in different ways in different contexts. In addition, an identity may be conceptualized 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 (Deschamps & Devos, 1998). This distinction between social and personal identities may further complicate positionalities.

In practice, engineering designers often incorrectly assume that good intentions are enough to make up for gaps in their understanding of fundamental conceptions in design for social good (Leydens & Lucena, 2017). A reflective awareness of the roles of positionality in 1) assessing contextual factors in design, 2) managing interpersonal dynamics, and 3) reflective awareness of intrapersonal dynamics is necessary for engineers to apply effective sociotechnical design approaches, however. Otherwise, engineers are likely to waste resources and do harm to intended project beneficiaries (Leydens & Lucena, 2017).

For example, recent research has demonstrated that an engineer must recognize and effectively account for contextual factors like broad structural, historical, and cultural problem contexts (Burleson et al., 2020; 2023) and power dynamics between themselves and other stakeholders in design work, both of which depend on an engineering designers' positionality (Fox et al., 2020). Similarly, biased or uninformed attitudes towards the stakeholders and contextual factors related to an engineer's work, which can arise from a poor understanding of positionality, have been shown to negatively affect interpersonal interactions between engineers and other stakeholders (Morgan et al., 2020). Moreover, reflection is required for an engineer to effectively account for the potential roles of their identities and personal motivations (Chou, 2020), as well their assumptions, values, and biases (Walji et al, 2020) in their design approaches and stakeholder relationships. Figure 4.1 summarizes the ways that positionalities affect design, where the contextual, interpersonal, and intrapersonal aspects of a design environment are interpreted by an engineering designer who, to whatever extent, may reflect and become aware of their positionalities and resulting intuitive attitudes and biases, then feed their reflective awareness back into the process of factoring information from a design environment into their design approaches. The lens in the center of the visual may be seen as the positionality of the engineering designer, but could also be applied to other stakeholders who influence design decisions and approaches.

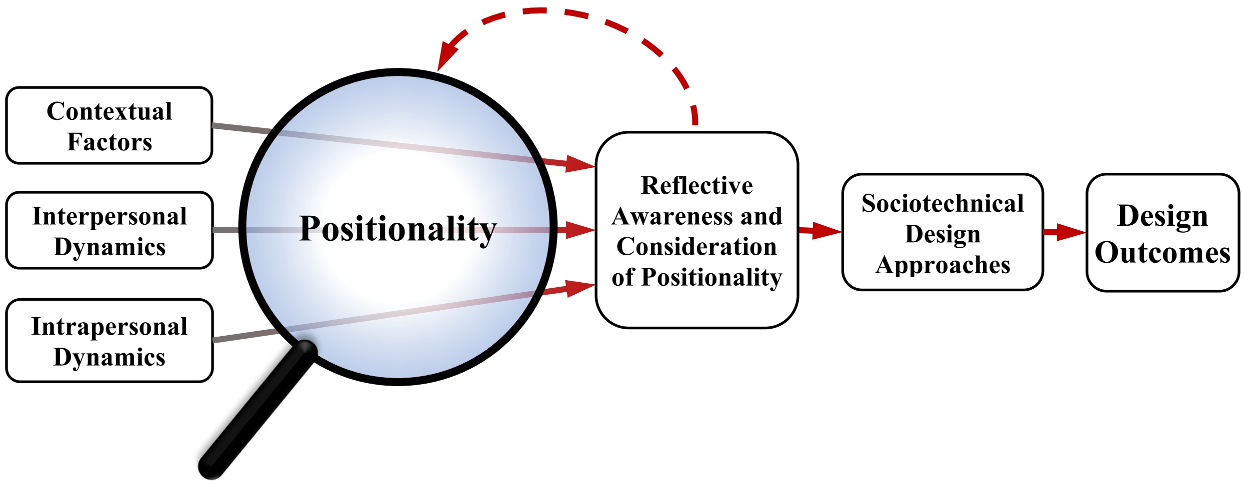


Figure 4.1 Reflective consideration and awareness of positionality in engineering design

Despite the fundamental importance of positionality in an engineer's approaches and the well-documented failures in professional and student design for social good projects, the notions that engineers are objective and that their identities are separate from their design work persist (Passow & Passow, 2017). This culture of depoliticization encourages engineers to separate and devalue social or non-technical elements from technical elements of design work, while discouraging critical assessment of social structures and norms (Cech, 2013). As a result, student engagement with social welfare has been shown to decline over the course of an engineering education (Cech, 2014).

4.3.2 Examples of the roles of positionality in engineering design work

There are many examples describing the consequences of poor consideration the role of positionality in professional and student design for social good practice, even though identity and positionality are often discussed implicitly or with different language. One example discussed the design of backdoor wheelchair access ramps in the US that allowed entry, but separated users from others who could walk through the front door of the same building, perpetuating rather than alleviating the marginalization of users with disabilities (Nieusma, 2004). Another case described an international development project where the US student and faculty engineers realized after the conclusion of a project that they had 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, resulting in project failure, damaged trust, and wasted time and effort on the part of Nicaraguan partners (Nieusma & Riley, 2010). The well-studied failure of the one laptop per child initiative to achieve its intended learning outcomes offers another example of the neglect of positionality in design for social good. Engineering and program designers have been criticized for projecting assumptions based on their own cultural and socioeconomic norms (James, 2017; Warschauer & Ames, 2010) that led to ineffective design across cultural and economic differences. The design failures in this initiative perpetuated inequitable power dynamics between the Global North and South in development initiatives, led to one of the greatest financial wastes in the history of international development, and likely caused economic harm to the intended beneficiaries due to the flooding of markets with donated goods (James, 2017) in addition to harm to individual students and educators who were disrupted by the program. Beyond the limited available research related to positionality in engineering literature, poor consideration of positionality has been widely shown to cause designed interventions for 'social good' to be ineffective or to perpetuate, rather than alleviate, systemic injustices. Examples include academic research design and interventions for social justice (Pasque et al., 2022), social business strategy design (Wydick et al., 2016) and program design for international development (Warschauer & Ames, 2010).

While current literature describes multiple ways in which positionality is important in design, few studies explicitly consider identity or positionality in engineering design, and no studies consider the various ways that positionality may come into play in engineering design, as was shown in Figure 4.1. How different implications of positionality come together to influence engineering design and designers, as well as how different engineers conceptualize and integrate concepts related to positionality into engineering work, are not known.

4.3.3 Strategies for Teaching Positionality and Related Concepts

A framework that offers insight into the development of skills related to the consideration of positionality is the Developmental Model of Intercultural Maturity (DMIM) (King & Baxter Magolda, 2005), which names specific attitudes and behaviors that represent initial, intermediate, and mature levels of development in conceptions of cultural differences. In the DMIM, culture is connected to categories like national, regional, and ethnic identity differences. According to the Oxford English dictionary, culture may be defined broadly as “the customs, arts, social institutions, and achievements of a particular nation, people, or other social group,” so the DMIM may reasonably be applied to a broad range of identities that shape social groups.

Examples of immature conceptions of culture described by the DMIM result in assumptions that unfamiliar perspectives are wrong, or limited awareness of personal values and other 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 one’s identity. 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, and valuing differences in interactions with others. Each level of maturity is further divided into cognitive, intrapersonal, and intrapersonal domains. In addition, the development of identity with respect to self-authorship has been characterized as 1) circular or iterative as opposed to linear, and 2) tending to facilitate stronger interpersonal relationships rather than hinder them as people develop differently over time

(Magolda, 2008), suggesting that increasing the maturity of one's conceptions takes time, but likely has positive benefits for engineering designers and design relationships.

In addition, 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 (Fayolle A, Gailly, 2015) and global leadership (Caligiuri P, Tarique, 2009) have developed and implemented education to improve students' fundamental conceptions of their own design practice, demonstrating that poor awareness of biases and positionality may be improved through strategic education. Similarly, guidance has been developed for researchers to better consider their positionality while designing and implementing research. For example, Milner (2007) proposed a framework to integrate a holistic assessment of a researcher's self, reflective processes, relationships, and understanding of broader context into the relatively isolated, specific research questions that typically guide scholarly research design.

4.4 Methods

The aim of this study was to investigate how engineering designers conceptualized positionality in their design applications for social good. Additionally, we examined their responses when exposed to training materials and reflective activities related to positionality. Our research was driven by the following questions:

1. In what ways do engineering designers across a range of experience levels narrate conceptions related to positionality in early-stage design for social good work?
2. How do engineering designers across a range of experience levels discuss A) the development of their conceptions of positionality in early-stage design for social good, and B) their reaction to using a positionality exploration and training tool?

4.4.1 Participants

Ten undergraduate engineering student participants were recruited from co-curricular design programs at the University of Michigan, and ten engineering design practitioners were recruited from the authors' professional networks. All participants were engaged in engineering design for social good work, and all practitioner participants had at least three years of professional design experience. Purposive, disproportionate sampling was used to ensure that participants with a range of identities and personal and professional experiences were included, as is recommended by (Bernard et al., 2016) for exploration of previously unstudied phenomena. A representative sampling of largely white, male engineering education programs and industries may have resulted in less or no consideration of the broader perspectives that individuals with other identities and resulting positionalities are likely to hold, as per a related study on service learning (Winans-Solis, 2014). The sample was split between engineering practitioners and students to increase the diversity of engineering contexts considered in this research versus a purely student- or practitioner-focused study. The overall sample size of 20 used in this study is in line with recommendations for qualitative, interview-based research (Hennik et al., 2022). Related interview-based studies of technical designer conceptions have used similar sample sizes (e.g., Burleson et al., 2022). General participant demographic details for student and practitioner participants are listed in Table 4.1 and Table 4.2, respectively.

Table 4.1 Student participant demographics

Student Participant	Gender	Year in Engineering Program	Design Project Focus
1	Woman	Fourth	Health product design for a low-income context
2	Man	Second	Health product design for a low-income context
3	Woman	Fourth	Environmental sustainability design for a high-income context
4	Non-binary	First	Health product design for high- and low-income contexts
5	Woman	Third	Health product design for a low-income context
6	Man	Third	Environmental sustainability design for a high-income context
7	Woman	Fourth	Health product design for a low-income context
8	Man	Fourth	Community development design for a low-income context
9	Man	Third	Community development design for a low-income context
10	Man	Fourth	Community development design for a high-income context

Table 4.2 Practitioner participant demographics

Practitioner Participant	Gender	Years of Prof. Design Experience	Design Project Focus
1	Man	9	Community development design for a low-income context
2	Man	5	Socially focused product design for a low-income context
3	Man	4	Environmental sustainability design for a high-income context
4	Man	4	Community development design for a high-income context
5	Man	10	Socially focused product design for a low-income context
6	Woman	5	Community development design for a low-income context
7	Non-Binary	7	Socially focused product design for a high-income context

8	Woman	5	Socially focused product design for a low-income context
9	Man	13	Community development design for a low-income context
10	Man	10	Socially focused product design for a high-income context

To preserve participant anonymity, additional participant demographics are given in aggregate, rather than in Tables 4.1 and 4.2. Regarding student participant demographics:

- Six of the ten student participants were non-white or of mixed race/ethnicity.
- Three identified as LGBTQ+.
- Two were first-generation immigrants from a non-Western country, two were second generation immigrants with one or more parents from a non-Western country, two were born and raised in a non-Western country.

Regarding practitioner participant demographics:

- Eight of the ten practitioner participants were non-white or of mixed race or ethnicity.
- Three were first- or second-generation immigrants to the United States from a non-Western country, and two were born, raised, and currently working in non-Western countries.
- All were practicing engineering designers (n=8) industrial designers (n=2) who develop technical products or systems.

The University of Michigan Institutional Review Board (IRB) reviewed and granted an exemption to this study. Consent was obtained from each participant prior to participation in the study.

4.4.2 Data Collection

Data collection proceeded according to the following: 1) participants were presented a document with key definitions and concepts to participants to ensure that each was similarly prepared to participate regardless of prior knowledge, 2) participants were asked to reflect during a writing activity about possible roles of their and stakeholders' positionality in a previous design experience, and 3) participants engaged in a semi-structured interview to debrief and expand upon conceptions reported in the writing activity. The sequence of data collection activities is visualized in Figure 4.2.

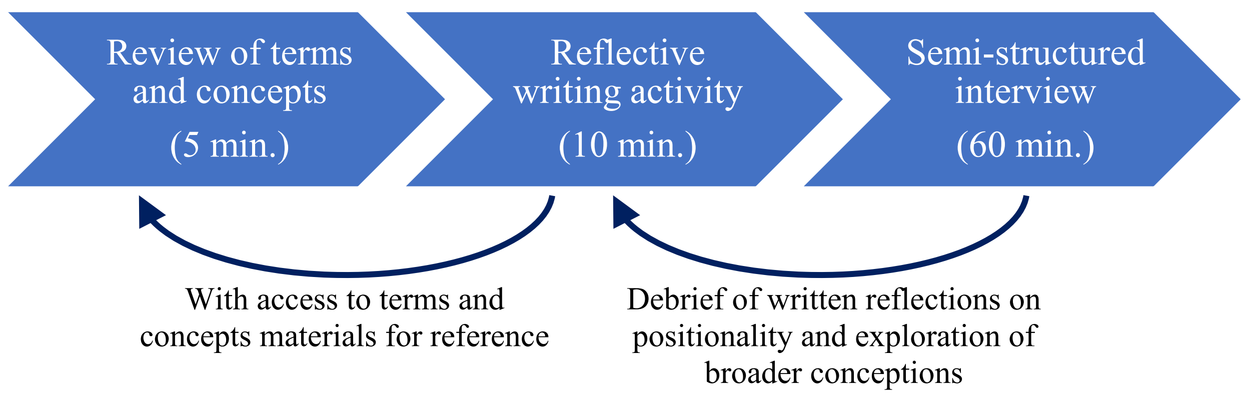


Figure 4.2 Sequence of data collection activities

All data collection activities were conducted at the same time during one video call with a researcher that lasted approximately 75 minutes. Research protocols for student and practitioner participants were nearly identical, with small changes to the wording of some interview questions to better reflect academic and industry design contexts, respectively. The document containing key definitions and concepts was included as a result of pilot data collection with three graduate student engineers, which indicated that participants may have differing, limited definitions and understanding of key concepts required to engage with this research. This document was summarized and presented to each participant for about 5 minutes by a researcher at the start of the video call. Information in this document included:

- 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., Alcoff, 2005; Burleson et al., 2020; Merriam et al., 2001; Nieusma & Riley, 2010)
- A list of 23 possible categories of identities with definitions for each.

During the writing activity, participants were prompted to describe one or more design decisions within a single, past or ongoing, design for social good project, as well as ways that identities and positionalities may have affected design activities. For each design decision, participants were asked the following questions:

- 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.)
- Which of your identities were most relevant to the process of making this decision, if any?

Participants were asked to write for 5-10 minutes and were encouraged to refer back to the document with key definitions and concepts while writing, if desired. Writing was done in a shared electronic document also visible to the researcher.

The semi-structured interview was conducted once the participant finished their written responses. The interview was grounded in participant conceptions expressed during the writing activity, beginning with questions related to the specific design experience described by the participant, then expanding to discuss broader, generalized conceptions related to positionality. Example questions used in the data collection protocol are listed below:

- 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 a designer?
    - Are there any other important 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 a designer today, whether it was positive, negative, or neutral?
    - In what ways was participating in this research surprising to you, if any?

To support validity, the development of the writing activity and interview protocols was guided by 1) socially-focused design literature describing interactions amongst identity, stakeholders, and problem context (Burleson et al., 2020; Deardorff, 2011; Nieusma & Riley, 2010; Parkinson, 2009; Social Identity Wheel, 2022), 2) the DMIM (King & Baxter Magolda, 2005), which has been shown to be an effective framework for interview instruments in higher education (Baxter Magolda et al., 2010; Deardorf, 2011; Soria & Troisi, 2014), and 3) critical theories related to intersectionality and systemic inequality based on identity (Crenshaw, 2013; Ladson-Billings 2009), which have been used effectively in critical, qualitative engineering identity research (Dietz et al., 2019). The protocol was also piloted and refined with two graduate students before data were collected.

In addition, the development of the research protocol was supported by a design-based research (DBR) philosophy that included iteration, practitioner input, and the development of an intervention alongside scholarly research (Anderson & Shattuck, 2012). The writing activity and supporting information was co-developed with a prototype educational tool sharing similar prompts and supporting information, which is included in Appendix (section 4.8) at the end of this chapter. Both the educational tool and the writing activity were refined after use with the first five study participants (all student participants), the results of which are described in Chapter 3, and continuously refined during the course of the research described in this article. Specifically, additions and clarifications were made to prompt language and the list of identities provided to participants as we identified opportunities for improvement were through the data collection process. These changes were used in the parallel refinement of the prototype educational tool. Though the introduction of changes during the research process may reduce repeatability, high repeatability was not the goal of this qualitative, phenomenological study, which by its nature has limited repeatability due to the effects of researcher positionality, as is discussed in section 4.4.4.

4.4.3 Data Analysis

Interview recordings were transcribed and de-identified, then data were analyzed the data inductively to characterize ways engineering designers related to positionality that had not been identified by prior research. Inductive analysis, which is described by Creswell & Creswell (2017) as the development of emergent patterns of meaning as opposed to the assignment of predetermined codes or themes, was applied to the data in parallel to identify themes not explicitly discussed in existing literature. Themes were identified iteratively, as is suggested by Patton (2014) to allow for an understanding of the data to develop as transcripts were evaluated multiple times. Themes broadly related to positionality were developed and assigned to relevant excerpts in the data. These excerpts were then organized into the themes discussed in our findings. Student and practitioner data were analyzed separately, but using a shared list of themes. Whole transcripts were used as units of analysis, meaning we counted only the presence or absence of themes in each transcript, to avoid ambiguity in assigning meaning to the frequency with which individual participants discussed their conceptions.

We did not attempt to evaluate the overall maturity or quality of participants' design approaches or outcomes, but instead to clearly characterize participants' perspectives with respect to theory and published descriptions of identity and positionality. Similarly, we did not always attempt to distinguish between cognitive, intrapersonal, interpersonal domains of participants' conceptions described by the DMIM (King & Baxter Magolda, 2005), as cognitive reactions are not necessarily measurable with the interview protocol we used, nor was the distinction between intra- and inter-personal attitudes and behaviors necessarily a focus of this study.

4.4.4 Researcher Positionality

All authors have experience working with socially focused design research and education efforts. The first author also has experience as a student and professional with engineering design and manufacturing in the US and internationally, primarily for socially focused organizations. Therefore, our team has first-hand experience with how engineering designers work, think, and learn across a variety of design for social good contexts. We acknowledge that the identities of the research team represent a limited range of backgrounds and identities, however. All authors are white, Western, and do not share many of the minoritized identities held by some participants in this research. Additionally, the authors do 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 and presentation influenced the information participants were willing to share, as well. It is also worth noting that much 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 necessarily 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 is an exhaustive insight into students' perceptions. Instead, with our collective experience and positionalities in mind, we seek to provide a useful characterization of student perspectives that may support the development of inclusive design education and future research on positionality in design, including research conducted by teams with complementary identities and expertise to our own.

4.5 Findings

All themes relevant to our research questions are reported here. Counts of participants who reported each theme are provided to give an approximate sense of the prevalence of themes among student participants, practitioner participants, and overall, but are not meant to quantify the relative importance of themes.

4.5.1 Participant Conceptions of Positionality in Early-Stage Engineering Design for Social Good Work

Participants reported a range of conceptions about the role of positionality in design, a summary of which is shown in Table 4.3. Most participants described the importance of positionalities of stakeholders and engineering designers across design activities, as well as the potential for improving design processes through increased, strategic consideration of positionalities, although participants also acknowledged difficulty in conceptualizing and articulating the implications of positionality in design. They reported that considering positionalities is often done implicitly and in ways that are limited by available language. In general, while practitioner participants reported some themes more often than student participants, both sample populations reported similar conceptions of the roles of positionality in design. Some student participants reported stereotyped positionalities towards their own or others' identities, however.

Table 4.3 Key themes in participant conceptions of positionality in design

Theme reported by participants	**Count of participants who reported theme**	
	Practitioner participants	Student participants
A. Positionality is fundamental in the early stages of engineering design for social good	10	9
B. Poor awareness of positionality causes problems in the early stages of engineering design for social good	10	7
C. Positionality has broad, complex implications across different aspects of engineering design for social good		
Intrapersonal reflections	9	5
Interpersonal relationships	10	9
Interpretation of design context	10	7
D. Conceptions of which of participants' own identities were most important to them as engineering designers in social good work varied		
Professional qualifications or technical skill sets	3	2
Personality traits or beliefs	1	2
Multiple, distinct identity types or an intersectional, whole identity	6	6
E. Conceptions of positionality in engineering design for social good are often implicit and shaped by limitations in available language	7	4

4.5.1.1 Theme A: Positionality is fundamental in the early stages of engineering design for social good

When asked to discuss how positionalities do or do not affect their work, all 10 practitioner participants explicitly described the implications of positionality as critical in their design processes, while 7 of 10 student participants shared similar sentiments. For example, Practitioner Participant 5 reported that:

> *It [positionality] is a fundamental backbone of anything you deliver. Being aware of it affects the quality of your work a lot.*

When asked how positionality is most important in their work, several participants discussed the impacts of positionality as most impactful in specific, early-stage design activities related to identifying and defining problems. For example:

> *Always at the beginning of the project: the project scope, the alternatives that you present as feasible alternatives… I don't think you can get much more fundamental than that. I think your positionality affects how you connect, how you present those, what you present and how you really define your problem. (Practitioner Participant 6)*

Others also discussed positionality as playing an even more basic role in how an engineering designer views and positions themselves in a design system, as is exemplified in the following exchange between Practitioner Participant 5 and the interviewer (the first author):

> *From identifying and defining the problem [to] all of the engagement [with stakeholders]: knowing who you are, with whom you work, and where you work is quite key. (Practitioner Participant 5)*

So, would you say it is fair to say that identities and positionalities are most important when you're figuring out where you fit in the social dynamics of your particular design process or design context? (Interviewer)

Yeah (Practitioner Participant 5)

In contrast, two student participants did not report that they had explicitly thought about positionality as a part of design work before. For example, when asked the ways in which positionalities might be relevant or irrelevant in their work, Student Participant 3 said:

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

4.5.1.2 Theme B: Poor awareness of positionality causes problems in the early stages of engineering design for social good

In addition, 10 practitioner participants and 7 student participants reported that poor consideration of positionality can cause problems in design. For example, Student Participant 1 explained how she connected prior design project failures to poor awareness of positionalities resulting from 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 [poor design decisions], as well as socioeconomic status; maybe just not thinking of 'they can't afford this' ... 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]...

4.5.1.3 Theme C: Positionality has broad, complex implications across different aspects of engineering design for social good

Four practitioner participants and one student participant discussed how many or all types of identities and resulting positionalities can have complex impacts in design. For example, Practitioner Participant 6 said:

> *If I had to be honest with myself. Probably every time I make a decision [positionality is relevant]. I think when I was thinking through these [types of identities], it was easy to pick off the low hanging fruit [i.e., more commonly conceptualized identities] but I would say that they all probably affect everything*

Similarly, Participant Practitioner 3 discussed the dynamic nature of identities and resulting positionalities as contributing to the complexity of positionality in design:

> *Identities are very much in flux in time, let alone between people. So, it's really important to both acknowledge what your different identities are that you're bringing in, and there's probably a like sub in the word positionality because - I don't know how to use it properly - but to acknowledge your different identities and biases that you might have going in.*

In addition, participants discussed a variety of ways in which positionalities in design can affect a) interpretation of design context, b) interpersonal relationships, and c) intrapersonal reflections on design activities. Nine Practitioners discussed intrapersonal implications of positionality, while all ten discussed implications related to interpersonal relations and the assessment and interpretation of design context. In comparison, student participants discussed intrapersonal (n=6), interpersonal (n=9), and contextual (n=8) implications of positionality slightly less often with more emphasis on interpersonal relationships within design teams.

Practitioner Participant 6 summarized her conceptions of the importance of positionality in intrapersonal processes in design as follows:

I don't really feel like you can make a decision without inserting your personal beliefs and values. I think that's something that's just unavoidable. And I would say that is especially true when you are doing, quote unquote, design for good.

As an example of intrapersonal implications of positionality, Student Participant 4 described the potential impact of their and their team's specific identities on their positionalities and design approaches:

We've grown up in the United States, but we're all children of immigrants… So, we tried to bridge a lot of gaps that I think other designers might not have with differing [non-immigrant] identities. Or, conversely, we could have completely forgotten about plenty of things as a result of our very similar identities.

Practitioner Participant 9's discussion exemplified practitioner conceptions of the interpersonal implications of positionality in his design for social good work. Specifically, he discusses other stakeholders' positionality towards him due to his different socioeconomic status and regional origin:

I'm working with people from other socioeconomic contexts … I'm from the capital [of a] very centralized country. So, when I go to other parts, I'm from one side [and stakeholders have] a lot of thoughts about that, right? I think it's important. I try to bring my personal skills to show that … I know the street. I know how to talk with people and start to get their confidence.

Student Participant 4 shared similar experiences based on positionalities in her design teams:

Oftentimes I've been working with mostly white men of the same age - who did not listen to me. They kind of refuse to acknowledge my perspective in a lot of engineering situations. I was one of the only people of color in the classroom, and one of like 3 women, so that led to a lot of experiences… I'd have to really push to be heard in any sort of situation, regardless of my experience.

With respect to the interpretation of contextual factors, Practitioner Participant 5's discussion of engaging with stakeholders in new contexts for the purpose of exploring and understanding his positionalities towards different organizations, cultures, and national contexts:

So, since I moved a lot between organizations and countries and cultures, I tend to quickly include other stakeholders to see how my positionality is in the physical area or in the company that I am [working], because it always influences my outcome.

4.5.1.4 Theme D: Conceptions of which of participants' own identities were most important to them as engineering designers in social good work varied

A range of types of participants' own identities were named as most relevant to their positionalities in design work, including a) meritocratic views of engineering designer identity, b) expanded views of engineering designer identities related to personality traits, and c) more holistic or intersectional views of engineering designer identity. For example, three practitioner participants and two student participants described educational credentials and technical skill sets as the most important part of their identities as engineering designers, as is exemplified by Practitioner Participant 2:

Professional expertise. That is where I draw credibility.

Two practitioner participants and one student participants described aspects of their personalities as the identities that underpinned their positionalities in design:

It's tempting to go for professional expertise or professional connections [as most important]. But I strongly feel that personality traits are more important, because I think they are a bit the foundation of everything. (Practitioner Participant 5)

Six practitioner participants and six student participants discussed multiple distinct identity types as most important, or declined to select one or several identities and instead discussed their overall identities:

I think that everyone is all of these things, and I don't want someone just to see me as a woman, or an engineer or the fact that I can't run very far … you know what I mean? I don't necessarily want to be in a box. I think my hope would be that people would understand that we're all very complex. (Practitioner Participant 6)

In addition, a limited number of stereotyped positionalities towards stakeholders' or engineering designers' own identities were reported by two student participants. Student Participant 3's discussion of perceived limitations due to her identities are shown as an example:

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.

4.5.1.5 Theme E: Conceptions of positionality in engineering design for social good are often implicit and shaped by limitations in available language

Five practitioner participants and six student participants expressed an awareness of difficulties in conceptualizing positionality in design due to the implicitness of the concepts and lack of appropriate language. Practitioner Participant 6 summarized the implicitness of her awareness of positionality in design as follows:

I try to be aware of it, but I can't say that I would think about it day to day. I think I mostly think about it when I come to a tougher decision … I should say I'm aware of it, but I'm not conscious of it. Right?

Relatedly, five practitioner participants and one student participants also discussed limited language or clarity of concepts affecting their consideration of positionality in design. For example, Practitioner Participant 3 reported that:

The idea of positionality is very new to me. I wouldn't say surprising, but it's something I'm still trying to come up with a spot in my brain for … where does this word exist? Right now, it's in between identity and biases, and how a person's life and actions kind of crosses that line and intermingles.

In addition, different participants described using a variety of different terms to formulate concepts related to positionality. For example, when asked what language they use in their own reflective processes related to positionality, Practitioner Participant 1 said:

I usually use context… It's just your biases. It could be good or bad. But it's bias.

Practitioner Participant 7 reflected on the possible political connotation of language related positionality in design, as well, noting that different words may have different, potentially charged meanings for different engineering designers or other stakeholders.

Identity and positionality are more neutral, inclusive ways of saying accessible and inclusive, I think. Accessible and inclusive are kind of "hot," you know – politically correct – and people kind of shy away from them. So, I appreciate that language *specifically. It lowers the stakes I find, and is a different way of welcoming people in, which I appreciate.*

4.5.2 Development of participant conceptions of positionality in design for social good

Participants discussed exposure to difference as the driver for development of their own conceptions of positionality, though many also admitted difficulty and described the process of learning about the implications of positionality in design as an ongoing process. Participants also described the data collection activities in this study as a form of exposure to concepts.

4.5.2.1 Exposure to different contexts and identities is foundational in engineering designers' development of awareness of positionality and related implications in design

Participants across experience levels and identities described learning about positionality and its implications in design as facilitated by exposure to people with different identities and positionalities, as well as to different contexts. All practitioner participants and nine student participants discussed ways in which they had learned about positionality in design through exposure to these types of difference in their personal lives, formal education, and/or design work. Practitioner Participants 3 and 6 summarized the importance of exposure to difference as follows:

Exposure is the bottom, bottom, bottom line. (Practitioner Participant 3)

If I could sum it up, it would be exposure, you know, exposure outside of my bubble at the core of it; the more people you meet and meeting people who are more of a global majority than what I might be typically exposed to… and especially socioeconomic differences. (Practitioner Participant 6)

Half of participants (six practitioner participants and four student participants), all but one of whom reported cisgendered, heterosexual male and/or White European or American identities, reported learning the most about positionality through exposure to people with diverse identities and positionalities during formal education. For example:

> *[College] was when [I started learning about] all the different ways that people are wronged in the world, and I didn't really care until then, because I didn't really know. Since then, I've thought more and more and more about identity. (Practitioner Participant 3)*

> *In college I feel like I found myself in really diverse groups, especially in the [global design ethics] class … I was the only straight white male in the class of like 35. I was often called out for isolated behaviors, and it wasn't overly accusatory but kind of like a 'hey, that's not a super appropriate joke, why don't we backtrack on that?' I think that was a really good space. (Practitioner Participant 4)*

Other participants, all with non-white, female, and/or LGBTQ+ identities consistently discussed learning the most about positionality through life experiences outside of design or education (Two practitioner participants and six student participants), often in ways that directly related to their own minoritized identities.

> *I personally already have that attitude [that positionality is important in design] because my family's from [a low-income country], and I've had experience working with the clinics there and I know the lack of resources that they have. (Student Participant 1)*

4.5.2.2 Learning about the implications of positionality in design processes is often implicit and difficult, but valuable

Five practitioner participants and one student participant discussed difficulties in their own process of learning about and incorporating implications of positionality more explicitly in design. Practitioner Participant 6 shared this sentiment while describing her own learning process regarding the implications of positionality in design and in general:

> *I'm going through my own learning process of how to identify my positionality, and so for now I would say I have some of these feelings about some of these [concepts related to positionality], but I don't know that I would necessarily have had the words or the organization in my head if I wasn't … really being intentional about unpacking that.*

Participant Practitioner 4 additionally emphasized the difficulty of understanding one's own positionality:

> *I would say that [positionality] can never fully be understood … you do a lot of hard work and have a lot of deep conversations to really understand your positionality.*

Seven practitioner participants and five student participants also discussed how they would find value in more explicit consideration of positionality in their design practice. For example, Practitioner Participant 3 reported:

> *I think it definitely would have added value [to discuss implications of positionality more explicitly] … if you talk about your biases upfront in the design process, it's easy to both acknowledge them if they're bad or incorporate them if they're good in terms of serving your end customer.*

4.5.2.3 Exposure to language related to positionality and types of identities, as well as structured tools for reflection on positionality in design, can help engineering designers consider positionality in design

Most participants (10 practitioner participants and 6 student participants) reported that they would not have independently come up with or were not familiar with all the identity types presented to them during data collection. For example, Practitioner Participant 6 said:

I would have come up with, for example, age, [national] origin, language, race, gender, sex sexual orientation … I hate to say this, but some of the more obvious ones. I don't think I would have thought about physical appearance. I don't think I would have thought about personality traits, personal interests – some of those items… If I'm being honest, I probably would have come up with like 6 of them [out of the 23 categories provided].

Five practitioner participants and three student participants explicitly volunteered that they learned about positionality in design from participation in the data collection activities. For example:

Now I think, just from this session, I get that positionality could be a big factor in design processes. … That [includes all] identity types. (Practitioner Participant 2)

To be honest, this project I told you about … I feel weird that when I was designing, I never thought about an identity type or positionalities. Yes, I am learning in this interview. (Practitioner Participant 9)

In addition, two student participants reported that they did not learn from participation in the data collection activities, but that exposure to the included concepts and materials would provide value for their peers. For example, Student Participant 1 said:

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.

All student participants who expressed limited personal value in participation also acknowledged that they would not have connected all the identity types presented to them in the data collection materials to design, however, indicating that while they may have felt that other students could have benefited more from training related to positionality, these student participants also likely have skills or conceptions that could be further developed through training.

4.6 Discussion

4.6.1 Positionality is fundamental to design work, but is often implicit and difficult to account for

While participants often discussed positionality as an implicit factor in design processes and with different language, student and practitioner participants consistently expressed an awareness of positionality and its potential implications in design, especially in early stages of design when engagement with stakeholders and context is most influential. Though some expressed strategies for accounting for aspects of positionality in design, no participants articulated holistic strategies for explicitly accounting for each of the impacts of positionality they described as relevant to design. Participants' reflections on the value in understanding and accounting for positionality explicitly in design highlight the mismatch between the fundamental importance of positionality in design and its neglect in engineering education and practice, which aligns with previous research describing apolitical (Karwat et al., 2015) and meritocratic, positivistic (Cech, 2013) characteristics of engineering cultures. This disconnect between awareness of positionality in engineering design and the availability of explicit skillsets to incorporate positionality into design approaches is not clearly described in existing literature, however.

4.6.2 Exposure to different people and contexts drives learning about positionality in design

Across participants, exposure to different contexts, identities, and positionalities through work, formal education, and/or other life experiences was named as driving the development of understanding of positionality in design. These findings have not been described in previous engineering literature, but align with established theories connecting learning to exposure to different ideas and contexts (Astin, 1999; Korthagen, 2010), and especially connecting learning to multiple modes of exposure. Moreover, participants who discussed the role of their own identities in their design work most explicitly also tended to hold one or more identities that are minoritized in engineering populations, demonstrating that depth of their personal experiences with difference may have provided greater awareness of possible implications of positionality than exposure to difference through work or formal education, which are optional as opposed to forced by societal norms related to identities and discrimination (Ladson-Billings, 2009). In contrast, participants with privileged identities (i.e., cisgendered, heterosexual male and/or majority racial or ethnic identities) often reported formal education as the venue where they learned the most about the implications of positionality in design, as they were not exposed to difference in comparable depth earlier in their lives. This lack of previous exposure has been documented in previous research on engineering students with privileged identities (Eastman et al., 2019).

The data collected in this study does not allow for us to measure the depth of understanding of positionality, nor to correlate conceptions of positionality with design outcomes, but these findings do indicate that engineering designers with minoritized identities are likely to have long-standing personal experience with differences in identities and/or contexts with possible implications for awareness of positionality in design. The data does not suggest that knowledge gained from exposure to specific differences in identities or contexts transfers to others, however, and given the intersectional nature of identity, it is likely that specific experiences with implications of positionality in design has limited transferability between design contexts. Different design for social good contexts and relevant stakeholders have unique characteristics and needs, and must be approached as such if engineering designers are to solve problems effectively (Nieusma and Riley, 2010). Participants with more personal or professional experience with differences did not indicate that they were more adept at designing in new contexts, only that they were more likely to be aware of positionality as a factor in design approaches. In addition, which identities are privileged or marginalized depends on context. For example, male participants with majority racial or ethnic identities in their country of residence in the Global South reported similar conceptions and experiences to White male participants in the United States. It is likely that neither group had large amounts of personal exposure to difference before their education and career compared to participants with identities that were minoritized during their upbringing.

Though practitioner participants may have had more exposure than student participants to different design contexts and types of stakeholders, there was not a clear gap between many student and practitioner participant conceptions of positionality, especially compared to other studies that have demonstrated consistent differences between novice and expert early-stage design skill sets (e.g., Deininger et al., 2017, 2019). This overlap between student and practitioner conceptions further supports the importance of life experiences beyond work and education for the development of conceptions of positionality in design. In addition, student participants expressed less uncertainty about language related to identity and positionality than practitioner participants. This difference in reported comfort with language may be an effect of student participants' greater exposure to inclusive language and consciousness of identities in university environments, generational differences, and/or overconfidence or limited reflection on limitations in their conceptions compared to practitioner participants.

4.6.3 Effects of sampling and transferability of findings to broader engineering populations

This study was designed to sample participants who were likely to demonstrate a breadth of perspectives on positionality in design due to differences in their identities, as well as a range of experiences with different design contexts and stakeholders. The majority of participants expressed a personal interest in positionality, equity, inclusivity, etc., in design as a reason for participation, however. Though study participants may have been able to offer more complete, reflective conceptions of positionality than the average engineering designer, the identities of these sample populations are not representative of the broader engineering and STEM populations engaged in design for social good. Participants in this study were 60% male and 30% White, and only 15% identified as cisgendered, heterosexual White men, whereas engineering student graduates in the US are approximately 78.1% male and 61.5% White, based on data from 2018 (ASEE, 2019), it is likely that the average engineering graduate has less personal experience with the types of exposure that support the development of conceptions of positionality in design. In addition, it may also be that some of the engineers who were not interested in participation may be uninterested or unwilling to engage with concepts related to positionality, as has been found in a study of the role of privileged identities in engineers' conceptions (Eastman et al., 2019).

While a few student participants expressed unfamiliarity with basic concepts related to positionality in ways that were not reported by any practitioner participants, this difference may also be a result of sampling practices rather than broader differences between student and practitioner populations. Though all practitioner participants expressed a personal interest or motivation to participate, this was not the case for all student participants, some of whom reported participating out of general curiosity or did not express a particular motivation to participate.

4.6.4 Limitations

This study is limited to data from the interview-based methods used. Future research may include observational or other methods to collect data on actual student design behavior and design outcomes. Survey-based methods, in particular, could be used to access and explore perceptions of more representative samples of engineering populations who do not have the personal motivation to participate in more in-depth research studies, and to do so in an anonymous way that would be less likely to encourage self-censoring. 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, as well as the ways in which the data may be interpreted. Future research may also evaluate specific strategies for training on the implications of positionality in design, or connect positionality directly to design outcomes, which are not attempted in this work. Design contexts beyond design for social good and outside of the early stages of design may also be explored.

4.6.5 Implications for design training and practice

This study demonstrates that even engineering designers who may be intrinsically motivated to consider implications of positionality in their design work do not necessarily have the language or strategies to do so explicitly or in ways that can be easily communicated to design team members or other project stakeholders. Student and practitioner participants reported unfamiliarity with types of identities (10 practitioner participants and 6 student participants) and 5 practitioner participants and 3 student participants volunteered that they learned something new related to positionality in design through the data collection activities of this study, which included the presentation of defined terminology and a list of possible types of identities. These findings indicate that exposure to language and definitions of types of identities and concepts related to positionality may support individual engineering designers and design teams in reflecting and communicating about positionality more explicitly and effectively. Familiarization with language for concepts related to positionality, as well as types of identities that may be relevant in design, can provide engineering designers with structure to think about identity and positionality more explicitly and effectively. In addition, strategies developed in other types of design, such as research design, may be relevant to the development of strategies for the awareness and consideration of positionality in engineering design. As an example, Milner's (2007) framework for holistic consideration of self, others, and context to account for positionality in research design suggests that when designing research, scholars frequently ask themselves "why" and "how do I know" in a systematic way to challenge the unfounded assumptions and biases that each of us hold and apply to our design decisions. As these types of training are not typically provided to engineering designers at any level, they may be beneficial additions to engineering education and workplace training.

In addition, the clear impact of participants' own privileged or minoritized identities and resulting life experiences on learning about the implications of positionality suggest that within engineering design populations, there are likely to be large differences in conceptions due to differences in identities. Similar findings have been reported across engineering literature related to educational experiences (Chang et al., 2014) and team dynamics (Joshi, 2014). Unlike technical skills that are traditionally accepted and evaluated in design training, effective training for the awareness and consideration of positionality in design would likely need to differ for different engineering designers depending on their base skill levels as well as their motivation to engage with positionality as a valid part of engineering design.

Moreover, for many engineering students, especially those without minoritized identities, their first meaningful exposure to different types of identities and perspectives may be during their university education (Eastman et al., 2019). Several practitioner participants (e.g., Practitioner Participant 4) cited discussions with peers with diverse identities and perspectives during their undergraduate education as driving their own reflection and understanding of positionality. Therefore, an engineering undergraduate experience is a critical time for strategic, intentional support of students' learning about the implications of positionality in design and more broadly before they begin professional work. Besides benefiting engineering students with privileged identities and the stakeholders of the projects they contribute to as practitioners, greater awareness of positionality amongst engineering student populations may also help to mitigate well-documented problems related to recruitment (Ohland et al., 2011), persistence (Chang et al., 2014), and discriminatory experiences (Joshi, 2014) shared by students with minoritized identities across STEM programs.

4.7 Conclusion

This study presents conceptions of positionality in design held by engineering students and practitioners engaged in design for social good, as well as explores how participant conceptions of positionality may develop. Key findings include a perception that positionality has fundamental importance in shaping design activities, especially in the early stages, yet is difficult to conceptualize and lacks consistent, explicit language in engineering circles. In addition, participants reported exposure to different identities, positionalities, and contexts through work, education, or their personal lives as driving awareness of the implications of positionality in design. These results highlight the gap between technically focused, positivistic engineering curricula and cultures and the need for strategic, intentional consideration of positionality in design practice and education. Specifically, we recommend that training include 1) explicit language and definitions related to identity types and positionality in design and 2) prompts to encourage individual reflection and group discussions amongst engineering designers on experiences with implications of positionality. While this study focuses on the early stages of socially connected design where differences in identities between engineering designers and other stakeholders are likely to be larger and encountered more frequently, effective consideration of positionality has the potential to benefit design outcomes, engineering designers, and other stakeholders across design applications.

4.8 Appendix: Prototype Positionality Training Tool

Figure 4.3 Prototype Positionality Training Tool

Designer Positionality Tool

These descriptions may be helpful as you explore how your positionality as a person and a designer can/ could impact your design work.

1. What is positionality and why does it matter in design?

Positionality can be defined as 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 identities shape your interactions with the world around you, including every interaction you have with other stakeholders in your work as a designer!

Positionalities are constantly, dynamically shaping the perceptions and behaviors of designers and other stakeholders whether or not we think about it, and positionalities are different in different design contexts, so it's important that we learn to consider positionality strategically in our work. Inadequate consideration of positionality in engineering is responsible for many past engineering failures and inequities, but when used intentionally, an understanding of positionality can also help us to engage with stakeholders and reflect on our own design approaches more effectively. Our goal should be to leverage the positive impacts of positionality in design while mitigating the negative impacts.

2. Examples of positionality in design

Positionality can feel like an abstract concept in engineering design, so please consider the following general examples to help ground the impacts of positionality in design practice:

Example 1: The types of stakeholders and research on design problem context you include or exclude when making design decisions can be influenced by your positionalities towards these stakeholders and design contexts.

Example 2: The quality of the interaction between you and project stakeholders may be shaped by both your positionality towards them, as well as their positionality towards you. Either can impact the information you are able to collect from them.

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

In each example, the impacts of positionality could be **positive and/*or* negative** on your design process. You can probably imagine cases where certain positionalities, such as those related to shared identities, could facilitate positive, productive interactions and understanding between stakeholders. You can probably also imagine cases where other positionalities could lead to biases, exclusion, or oversights with negative impacts on design outcomes.

3. Visualizing positionality in design

This visualization offers another way to describe the roles of positionality as part of a design "ecosystem," where each element of the model interacts with the others, and the designer is centered as an actor within the ecosystem. Each element of the model is described below:

Blue Circles **— Design environment**
Where design happens, who is there, what problems and resources they have, what is affected by design problems and solutions, etc.

Orange Rectangle **— Design Process**
The systematic problem-solving approach used by you and your team.

Yellow Arrows **— Connecting Activities**
Inputs like information gathering, or outputs related to implementation and the impacts of your design.

Red Dashed Line **— Your filter or *positionality***
Who you are, what your motivations, priorities, values, and biases are, and how all of this affects the information you seek out, how you interpret it, how you relate to other stakeholders, and how they relate to you.

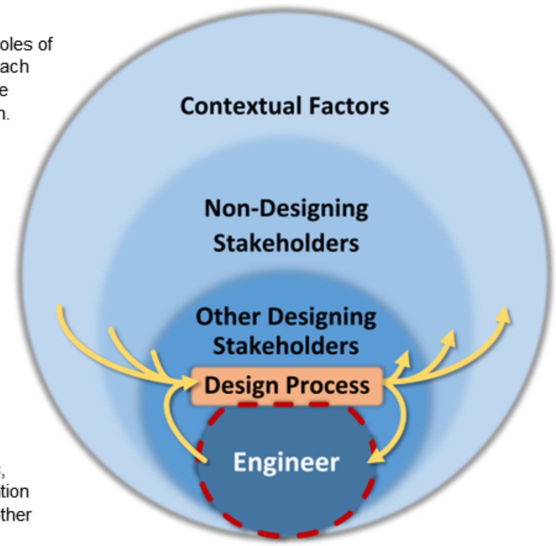


Figure 4.3 (continued)

1. Consider your identities
Name at least three types of identities you have to consider in the context of your work as an engineering designer (Refer to identities list as needed). For each identity type, name your identity and write one sentence describing an effect that this identity might have on your positionality as a designer, or on other stakeholders' positionalities towards you. *(Please only include identities you are comfortable sharing.)*

2. Explore the effects of your positionality as a designer on your work
A. Choose a current or past design project to describe:

Project	
Project purpose	
Person or organization in charge of design	
Your role	
Current project status (and outcomes)	

B. Exploring Design Decisions

	Describe a design decision you made/ to be made in the project you used in part 2A	**Which of your identities were/are most relevant to this decision?** (Refer to identities list on the next slide as needed)	**Which information sources did you primarily use to inform this decision?** (e.g., 'design ecosystem' environment elements like your own background knowledge, your team or organization, other stakeholders, or by researching aspects of the problem context. See the expanded definitions of design environment in the 'design ecosystem' model on the next slide, if necessary)	**Reflect on the ways in which the design decision you described may have been/ be affected by the identity(s) you listed and resulting positionalities**. In what ways do you think those identities may have interacted with the [stakeholders *or design* context] you described as important to the decision-making process?
1				
2				
3				

Figure 4.3 (continued)

Identity Type	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
Geo-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	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.
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 you implicitly or explicitly subscribe to
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
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

Design Environment Definitions in the "Ecosystem" Model

The blue circles in the design "ecosystem" describe all the people and contextual factors that are involved in the activities of a design process, including:

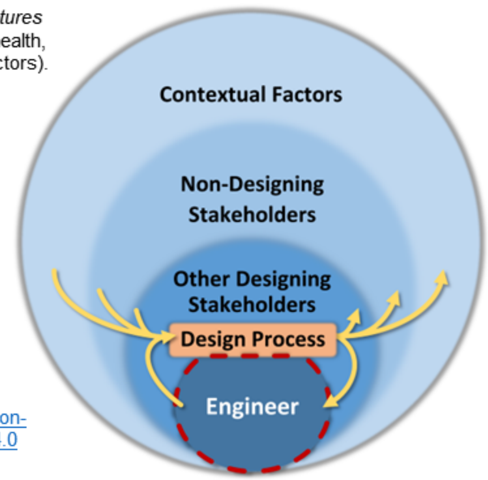
1. The designer (you) who collects, interprets, and applies information from other elements of the system (and from your own knowledge) to your design work.

2. Designing stakeholders including your immediate design team, other co-designers, as well as anyone else who contributes directly to design decisions.

3. Non-designing stakeholders including stakeholders within your organization and external stakeholders, such as manufacturers, investors, etc. who have an interest in the outcome of your work but do not contribute directly to decisions.

4. Broader contextual factors surrounding a design problem that may influence your design decisions, including:

- *Socio-cultural factors* (e.g., work cultures, conceptions of time and timeliness, taboos, etc.).
- *Physical environment* (e.g., infrastructure, geography, and environmental factors).
- *Technical factors* (e.g., manufacturing and industrial factors, technical feasibility).
- *Social systems and structures* (e.g., institutions, public health, politics, and economic factors).



Chapter 5 Contributions, Implications, and Conclusions

This chapter summarizes the findings, implications, and contributions of this dissertation. First, the main themes from Chapters 2-4 are summarized. A framework for the consideration of people, context, and positionality in design that encapsulates the studies in Chapters 2-4 is also proposed. The chapter ends with a summary of implications, limitations, and overall conclusions.

5.1 Reflective consideration of people, context, and self are fundamental in early-stage, engineering design for social good, yet is often undefined and undervalued in engineering education and culture

Findings in this dissertation align with previous research calling for the consideration of individual differences in people (Fox et al., 2020), design context (Burleson et al., 2020; 2023), and reflection on a engineering designer's self (Chou, 2020; Walji et al., 2020) as critical for effective socially engaged design, especially in the early stages when projects are likely to be set up for success or failure (Cooper, 2019). Findings also align with calls for the integration of non-Western design perspectives that encourage more holistic design approaches to support positive social outcomes (e.g., Butoliya, 2018). Most participants across the studies in Chapters 2-4 described reflectively adjusting their design approaches to new stakeholders and design contexts, whether in design activities like remote engagement of stakeholders with prototypes or more broadly in the consideration of positionality throughout the early stages of a design project.

Participants used disparate language to describe these reflective processes, however, and acknowledged that their processes were often implicit and difficult to articulate in part because of a lack of an explicit vocabulary for reflective design skills. In Chapter 2, even though not directly asked about identities or positionalities, participants discussed the expertise, professional position, nationality, age, and other identities of stakeholders as influencing the design and execution of remote engagements with prototypes. These discussions implicitly included implications of positionality in design work, though participants likely were not consciously thinking about their design experiences in terms of positionality. In Chapters 3 and 4 where participants were specifically asked to describe their conceptions of positionality and its implications in design, even participants who have substantial personal experience with positionality acknowledged that they lacked the language and mental constructs to fully understand or express their conceptions. These findings are in line with previous research describing the implicit nature of nontechnical skills in engineering design cultures (Bromberg & Polo, 2014).

The implicitness of nontechnical skills in engineering design, including the evaluation and consideration of stakeholders in remote engagements and of positionalities more broadly, limits the abilities of educators to design relevant curricula and implement them in the classroom within existing engineering education systems (McGowan & Bell, 2020). In addition, the lack of explicit conceptions of nontechnical skills in engineering populations likely perpetuates positivistic attitudes that may prevent individual engineers from considering design contexts and stakeholders broadly and open-mindedly (Kim et al., 2019), which is necessary for effective socially engaged design (Zoltowski et al., 2012). Some participants in Chapters 3 and 4 described similar sentiments, reporting ways that colleagues were unwilling or unable to engage with concepts related to positionality in design.

The lack of clarity and consistency in language reported by participants in Chapters 3 and 4, and resulting limitations to their conceptions, are likely to be indicative of broader issues with language across nontechnical engineering design skills, which are often undervalued (Itani & Srour, 2016). Related studies of engineers' conceptions of nontechnical skills, such as empathizing with stakeholders, have reported similar limitations in language (Walther et al., 2017). Individuals who have limited skill sets for the consideration of positionality and other nontechnical skills related to understanding stakeholders, contextual factors, or themselves as engineering designers, but are willing to learn, may be less able to improve their conceptions when different words are used by different people, and in different ways, to describe similar phenomena. Clarity in language may be especially important for engineers who are reticent or resistant to acknowledging well-documented implications of privilege associated with identities in engineering cultures and historical injustices related to engineering designs (e.g., Chang et al., 2014).

In addition, efforts to improve the clarity of language used for positionality and other nontechnical design skills should consider the current positions and limitations of engineering designer populations. For example, Practitioner Participant 7 in Chapter 4 described how "identity" and "positionality" are more neutral terms than, for example, "accessible" and "inclusive," which some engineers hold biases towards and dismiss as niche or unnecessarily political. Without excusing or enabling biased attitudes towards language like "accessible" and "inclusive," there may be opportunities for, in the words of Practitioner Participant 7, "welcoming people in" to an understanding of the value of nontechnical skill sets and equitable design practices with diplomatic, yet descriptive language that "lowers the stakes." Moreover, challenges due to implicit conceptions and language are not limited to engineering. Other applied disciplines, such as business management (Stainback & Tomaskovic-Devey, 2009) and public policy (Flood & Pease, 2005), have been cited as having similar cultural issues related to privilege and inclusion that likely have negative effects on design outcomes in those fields. Future work could explore similarities and differences in limitations across applied disciplines with the aim of supporting the transferability findings across disciplines, as well as supporting interdisciplinary education that enables students in each discipline to benefit from overlapping skills and perspectives from other disciplines (Van den Beemt et al., 2020).

Participants across studies described compounding difficulties when designing across distance and difference at the same time. For example, physical distance was described as limiting an engineering designer's ability to assess differences in stakeholders' perspectives, technical expertise, and attitude towards the engineering designer, which is in-line with previous studies of remote engineering design (e.g., Asadi et al., 2017; Larson et al., 2010). Distance and difference also intersect when engineering designers attempt to design and/or implement 'social good' projects remotely. Student and practitioner participants in Chapters 3 and 4 consistently discussed challenges in assessing unfamiliar, international design contexts when some or all design work was done from their home country, as has been found in related studies of international engineering design applications (e.g., Skokan & Munoz, 2006). These results, while expected, have not been fully explored in design for social good applications. Future work could systematically compare the impacts of physical distance and differences in identities, positionalities, and contexts, together and separately, on engineering design for social good. Such research could further inform recommended practices for socially engaged design across difference and difference, as well as characterize the requirements for effective, remote design for social good in ways that would help engineers decide whether and how to engage in this work.

Another aspect of reflective skill sets likely worthy of future study is individual engineering designers' understanding of their personal motivations to participate in "social good" work and prioritize or de-prioritize certain design outcomes, all of which may be driven by identities and positionalities. While motivation was not directly asked about in the studies in this dissertation and may be a difficult topic to explore explicitly through interview-based methods, alone, several participants alluded to different motivations to participate in design for social good as impacting the quality of design approaches and outcomes. For example, Student Participant 1 in Chapter 4 discussed how due to their identities, engineering students were motivated to participate in design for social good projects in part to bolster resumes, design for personal enjoyment, or other reasons that led to design approaches that were partly or entirely misaligned with achieving the best outcomes for the stated social goals of the project. A similar example of motivation impacting design approaches and outcomes was reported by Practitioner Participant 9 in Chapter 4, where he and his colleagues had conflicting motivations to prioritize either direct human needs or environmental conservation in a national development project, depending largely on their disciplinary backgrounds. In both cases, participants described the relative priority of different individual motivations as critical. In neither case were the engineering designers unmotivated to support positive social outcomes, but how they prioritized social benefits for end-users versus their own needs as engineers varied, as did how they determined which social benefits should be prioritized (and potentially, who's social benefits should be prioritized). Engineering designers' motivations to engage in design for social good, how they prioritize different and possibly competing personal motivations, and their reflective awareness of these intrapersonal processes, may have a critical, understudied impacts on design work. The study of engineering designer motivation may challenge many participants and be more difficult than exploring the comparatively neutral concepts of identity and positionality, but is likely to also be a more direct way to connect engineering designers' conceptions and skills to positive or negative design outcomes.

More broadly, future research may explicitly connect design outcomes to the consideration of positionality, remote engagement with stakeholders, and other stakeholder- and designer-facing design skills for the consideration of people, context, and self, which was not attempted in this dissertation. Future work may also explore ways to make concepts and language for nontechnical design skills more explicit and accepted in engineering cultures. Such research may further integrate the implications of positionality in design with related topics, such as research on contextual factors in engineering design (Burleson et al., 2020), engineering designers' personal and organizational context (Chou, 2020), and issues related to equity in engineering design outcomes (Nieusma and Riley, 2010), engineering education (Chang et al., 2014) and engineering culture more broadly.

5.2 The development of skills for more effective consideration of people, context, and self in socially engaged design is enabled by exposure to diverse identities and contexts

Across studies, participants described their abilities to consider different people and design contexts, as well as to dynamically consider positionalities, as driven by exposure to diverse identities and design contexts. This finding aligns with established theory describing learning as resulting from exposure to different people, ideas, and contexts (Astin, 2014). In addition, participants consistently described the development of their skills and conceptions as enabled by experiences in life, work, or education outside of formal engineering curricula. These results 1) indicate gaps between traditional engineering curricula and specific skills needed and used by engineering students and practitioners, and 2) provide direction for the types of experiences that may be used to better train engineering designers to incorporate people, context, and positionalities into their work.

The Accreditation Board for Engineering and Technology (ABET) calls for related nontechnical skills to support "solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" (ABET, 2023). It is not clear that the engineering training received by participants met the intent of these guidelines in the cases of the topics studied in this dissertation. Participants also reported that engineering teams do not necessarily discuss nontechnical skills explicitly, even if individual engineering designers use nontechnical skills implicitly or subconsciously. Future work may build on the experience of the participants in the included studies, encouraging exposure to difference as a part of engineering training as has been called for by other researchers (e.g., Morgan et al., 2020), as well as strategies to evaluate the effectiveness of this training in educational and workplace settings.

While exposure to difference was reported as supporting reflection and learning for the participants in the included studies, Chapters 3 and 4 draw on data from samples of engineering students and practitioners who represent a range of diverse identities, and who discussed personal motivation to engage with positionality in design, often due to their own minoritized identities or experience working across cultures. Therefore, the broader engineering population may possess less exposure to differences through their work and personal identities might lack the understanding and interest in positionality In design, resulting in less informed or even absent conceptions related to this aspect, in line with learning theory naming intrinsic motivation as a prerequisite for efficient internalization of experiences (Oudeyer et al., 2016). The example of team members who prioritized personal motivations to design over stakeholder benefit described by Student Participant 1 in Chapter 4 may be an example of less reflective engineering designers who did not learn, or did not learn as much as they could have, from an exposure to different identities and contexts. Education or workplace training aimed at broader engineering populations will need to account for a range of intrinsic motivation (or aversion) to engage with positionality in design and related reflective skills. One way to improve motivation may be to normalize the discussion and treatment of these skills in engineering education so that skills are less likely to be perceived as relatively unimportant, as has been found by Passow (2012).

Additional future research could explore the perspectives of design practitioners, students, and/or researchers with diverse identities on the balance of technical and non-technical, classroom-based, and experiential learning they would have found most effective in their design education. While engineering programs and ABET have increased the emphasis on nontechnical, socially focused skills and outcomes in recent decades (Morgan et al., 2020), it is not clear that the engineering program curricula and structures experienced by study participants in Chapters 3 and 4 support the nontechnical understanding of positionality many of them described as critical. Some participants, including those who completed their education within the last decade, specifically volunteered that their awareness of positionality and other nontechnical design competencies were not facilitated by engineering classes, but through humanities classes or other experiences on campus. As previous studies have found that a majority of engineering practitioners place less value on nontechnical competencies, such as understanding "contemporary issues" and "the impact of on''s work" compared to other engineering competencies named by ABET (Passow, 2012), there is likely to be a disconnect between the design and implementation of engineering education by researchers and others with privileged identities, and the set of technical and nontechnical skills needed by engineers to address social needs as effectively as possible. Though many researchers have called for improvements in engineering training related to the consideration of people, context, and self in various capacities, the inclusion and elevation of the perspectives of engineering designers with diverse identities and positionalities, specifically, as individuals who are likely to place more value on the nontechnical skill sets required by ABET, may be an undervalued opportunity in engineering education research.

5.3 Preliminary model for the consideration of people, context, and self in engineering design

A preliminary model was developed to more explicitly relate the implicit roles of differences in people, design contexts, and the engineering designer's self-described by study participants in Chapters 2–4. Shown in Figure 5.1, this visual integrates the various aspects of design work described by students and practitioners into the form of a social ecological model, which has been used to model human systems related to design in other applied disciplines such as healthcare and environmental policy design (e.g., Golden et al., 2015) in ways that emphasize the complexity and breadth of elements that influence, and are influenced by, a design process.

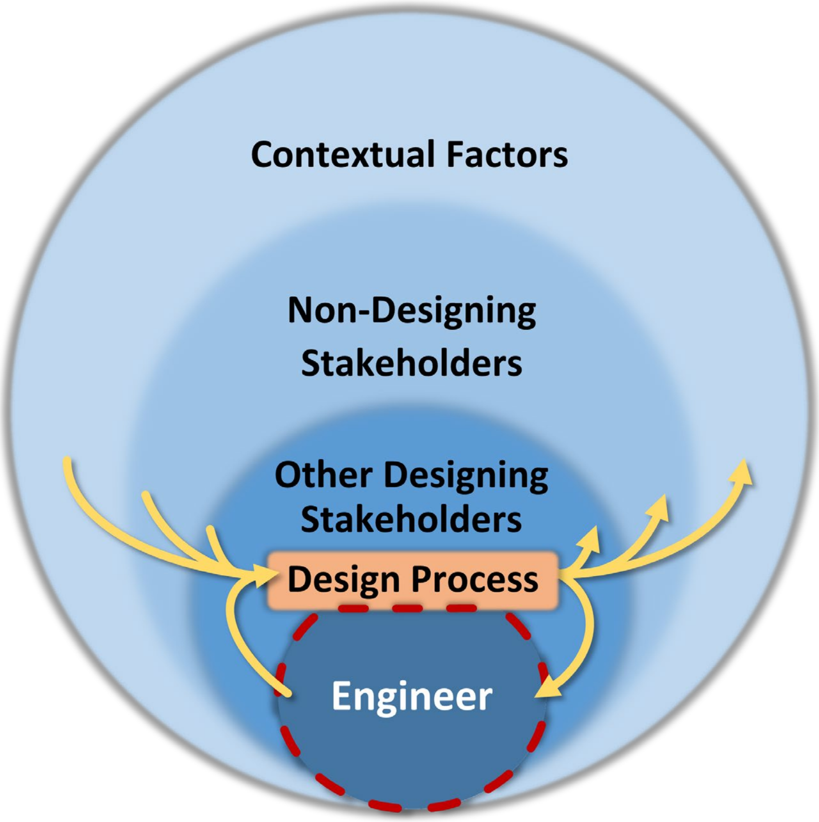


Figure 5.1 Proposed "design ecosystem" model of people, context, and positionality in engineering design

Figure 5.1 Legend

Blue — Design Environment: Where design happens, who is there, what problems and resources they have, who and what are affected by design problems and solutions, etc. **Orange — Design Process:** The structured problem-solving approach used by an engineering designer and their design team **Yellow — Connecting Activities:** E.g., inputs related to information gathering, or outputs related to the implementation and impacts of design **Red — The Engineer's Positionality:** Who an engineering designer is and what their motivations, priorities, values, and biases are; how all of this affects the information they seek out, how they interpret it, how they relate to other stakeholders and vice versa

5.3.1 Description of the preliminary design ecosystem model

In the model, the blue circles represent the design environment: all the people and contextual factors that affect, and are affected by, a design problem and solution. The inner circle represents the engineering designer, as they must interpret the other elements of the design environment to contribute to the design process. As all contributions to a design process, as well as all information used in a design process, including an engineer's prior knowledge, must be filtered through the engineering's personal lens, a dashed red line is drawn around the "engineer" circle to show the role of the engineering designer's positionality towards other parts of the design environment. "Other designing stakeholders" includes people who contribute to design decisions, including formal design team members and other stakeholders who participate in a design process. "Non designing stakeholders" are people who affect or are affected by the design problem and solution, but do not contribute directly to design decisions. While it is rarely feasible for all stakeholders to directly contribute to a design process in real-world engineering design problems, which stakeholders are invited to contribute is often determined by the engineer and core design team members in ways that are shaped by their positionalities towards other stakeholders. "Contextual factors" include everything non-human that is relevant: the physical environment, social norms and cultures of stakeholders, supply chains and infrastructure, politics and regulation, financial resources, etc. (Burleson et al., 2020; 2023). There may be overlap between the boundaries of each circle, but in general, the model is organized to show that elements closer to the center are ones an engineering designer has more direct influence over.

The orange "design process" block represents all the systematic decision making done by anyone who takes on the role of a designer. The block is situated between the engineering designer and other designing stakeholders, as they are the ones who operationalize the design process. We can consider the design process to be a "black box" for the purposes of this visual. Within it may be all the typical features of design processes such as divergence and convergence, iteration, front- and back-end design stages, etc. (Cooper, 2019), tailored to a given design problem.

The yellow arrows represent design activities that connect the design process to the ecosystem. Specifically, the design process draws on information from all levels of the design ecosystem (including the engineering designer and their prior knowledge), and in turn impacts all levels of the ecosystem during the design process and through the implementation of resulting design solutions, again including the engineering designer, who may reflect upon and learn from the design activities and outcomes. “Input” design activities may include user research, lifecycle analysis, product benchmarking, etc., and “output” activities may relate to analysis or testing used by the design team, implementation of solutions in the wider design environment, etc. The input and output activities are generally iterative during a design process (Cooper, 2019).

5.3.2 Uses of the preliminary design ecosystem model

In the context of this dissertation, the ecosystem model can be used to illustrate and relate the main findings from the chapters in this dissertation. For example, the strategies described in Chapter 2 for remote stakeholder engagement with prototypes connect to the “input” arrows connecting contextual factors (i.e., related to physical location and distance between engineering designer and stakeholder) and other stakeholders (i.e., the identities of the stakeholders that may influence their expertise and preferred communication styles) to the design process, where the engineering designer systematically considers these inputs in order to design effective prototype(s) and remote engagement strategies. In Chapters 3 and 4, participant conceptions of the implications of positionality with respect to other stakeholders, design context, and their own reflective processes can be mapped to the dotted red line, indicating the engineering designer’s positionality towards the various inputs and outputs.

This ecosystem model may also be used to support a more holistic view of design in support of future research or design training for externally facing design skills or internally facing reflective skills for socially engaged designers, which are often discussed and developed individually rather than holistically (e.g., Van den Beemtet al., 2020). This type of model and related efforts to connect or map different aspects of design may offer complementary ways to support the understanding of relatively abstract concepts like positionality. Participants in Chapters 3 and 4 discussed various ways that understanding the "big picture" of a design environment allowed them to better situate themselves in the design process and interact more effectively with other people and contextual factors. Similarly previous literature has encouraged, for example, seeing nontechnical skills related to reflection and engagement with stakeholders as a "creative process of reciprocation" rather than end-goals or boxes to be checked (Bennett and Rosner, 2019). This model may help to visualize the iterative, reciprocal nature of learning about and working with different elements of the design environment.

5.4 Limitations

The studies described in Chapters 2-4 share limitations related to the research methods used and researcher positionality. As data from all chapters are based on semi-structured interviews, other data collection methods such as observation, participant-observation, surveys, etc. would allow for triangulation and for complementary or more nuanced results. In addition, while findings may be transferable to a range of design stages, contexts, and industries, the qualitative nature of the studies does not allow for generalizability. Larger-scale studies based on this work that use quantitative or mixed methods across broader samples could increase the generalizability of results. In addition, and especially as much of the collected data relates to positionality, the limited number of disciplinary, social, and personal identities held by the research teams inevitably shaped the analyses of the included studies. Future work by researchers with different identities, including disciplinary expertise, would expand the range of insights possible from similar studies.

5.5 Implications for engineering design education and practice

The studies in Chapters 2-4 emphasize the importance of engineering designers' awareness and consideration of other people, contextual factors, and their own identities and positionalities in socially focused and increasingly globalized design environments. With respect to engineering education, these studies support the body of literature advocating for strategic, intentional inclusion of nontechnical (e.g., Nieusma & Riley, 2010) and especially reflective skills (e.g., Lousberg et al., 2020) in engineering design curricula. In addition, this work supports calls by other researchers for interdisciplinary education for engineers and other designers that borrow from well-established theory and language in the social sciences, such as anthropology (e.g., Anderson, 2021) and the humanities (e.g., Alcoff, 1988), where concepts like positionality are commonly integrated. Nontechnical and interdisciplinary education, specifically, have been shown to help engineering students put their technical skills into context and can support their abilities to create socially beneficial outcomes across applications of engineering design (Van den Beemt, 2020).

In workplace training applications related to conceptions of identity and positionality in design, there is indication from the findings of Chapters 3 and 4 that practitioners may not necessarily have received more training or hold conceptions that are more developed than students. Such training is not common in engineering education or practice (Fox et al., 2020; Walji et al., 2020) and individual engineering designers' conception appear to depend on their personal experiences, especially those related to their own marginalized identities, at least as much as other modes of learning. As such, training for practitioners may not necessarily differ from training for students in the same ways as for technical skills where practitioners are more advanced (e.g., Deininger et al., 2017; 2019). Both students and practitioners may benefit from training developed with support from the social sciences and humanities, beginning with fundamental conceptions and language that are uncommon or absent in engineering skill sets and cultures. Engineering practitioners may also benefit from the normalization of such nontechnical concepts in engineering cultures to support more explicit training and ongoing skills development.

Recommendations for training on the awareness and consideration of positionality in design are embodied by a preliminary reflective tool, included in the appendix to Chapter 4 (section 4.8), meant to help students and practitioners situate themselves in their work. The tool may be used as a training exercise before design projects or during design projects to guide design activities. A framework, also outlined in detail in section 5.3, for understanding and accounting for positionality based on literature and findings from Chapters 3 and 4 is provided in the tool, which includes 1) language for relevant ideas and types of identities that are often conceptualized implicitly in engineering design, if at all, and 2) prompts to encourage reflection and discussion among engineering designers, or among engineering designers and other stakeholders, to encourage accountability and expose personal blind spots as has been called for by researchers of socially focused design (e.g., Arshad-Ayaz et al., 2020), as well as to facilitate exposure and learning from others' experiences. Such exercises may also help to reduce common "othering" by engineering designers (McGee, 2021) as they build connections with people who have different identities and resulting life experiences, with implications for more equitable design approaches as well as possible improvements to the quality of engineering work environments (McGee, 2021) and educational experiences (Chang et al., 2014). As this tool is a prototype, future work can refine and validate the tool as well as develop related training methods for engineering education and workplace training.

Though the studies in this dissertation, especially in Chapters 3 and 4, explore socially focused engineering design, findings may transfer to engineering design more broadly, as well as design applications outside of engineering. Design for "social good" was chosen as a focus for the studies of positionality as differences in identities related to culture, socioeconomic status, etc., are typically larger and more obvious than in other design cases where engineering designers and other primary stakeholders, such as end users, have fewer or subtler differences in identities (e.g., domestic automotive design in the United States). While this hopefully enabled a clearer characterization of the implications of positionality in design, we do not mean to claim that the consideration of positionality and other reflective skills are less important in other design cases. In some ways, effort devoted to the skillful consideration of positionality may be more necessary outside of socially focused design where differences in identities and resulting power dynamics, biases, etc., are more difficult to expose (Baber et al., 2019). While there may be differences between the stakeholder- and designer-facing skills needed to consider people, context, and self effectively across applied disciplines, these skills are fundamental and not specific to engineering design or technical disciplines. Any design process that involves people besides the designer requires these skills to be completed effectively, and therefore the implications of this dissertation may be considered with respect to other disciplines that do design, as well.

5.6 Conclusions

This dissertation contributes to socially engaged engineering theory and methods by characterizing stakeholder-facing and reflective, designer-facing skills and concepts.

Specifically, the exploration of the implications of identities and positionalities in socially focused engineering design can support further research and help to normalize the integration of these concepts, which are well-developed and accepted concepts in the humanities and social sciences, into engineering disciplines. The studies in this dissertation also support calls in existing literature for improved reflective skills, holistic consideration of stakeholders and context, and broadly conceived, technical and nontechnical engineering education experiences. The preliminary social-ecological model of design in this chapter may also support holistic conceptions of design and design research related to, but not limited to, studies of positionality and socially focused design approaches.

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