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Intercultural Experiences of Engineering Students During Immersive Design Projects

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***Abstract* – Engineering graduates need to be equipped with intercultural design skills to address the increasingly globalized challenges facing societies, such as climate change and global health emergencies. University programs have developed immersive design or service-learning experiences to expose students directly to intercultural design contexts in hopes of supporting the growth of their intercultural design skills. How students apply and develop intercultural skills during often short-term immersive experiences is unclear, however. Through semi-structured interviews, this research study explores the ways in which twenty-one engineering students applied and developed intercultural skills in immersive, service-learning experiences. Our analysis identified patterns of reflection and learning related to cultural differences, cultural positionality, and personal biases, which were driven by exposure to stakeholders, broader design project environment, and pre-trip preparatory education. These findings suggest four main educational benefits of immersive, intercultural design experiences: (1) enabling engagement with cultural backgrounds students had not previously encountered, (2) increasing student motivation to engage with design impact through proximity to perceived social outcomes, (3) mentorship by individuals with expertise on project contexts, and (4) complementary educational opportunities provided by preparation for, and general exposure to, the design environment alongside actual design activities. Ultimately, the findings from this study have the potential to inform the design and facilitation of immersive experiences aimed at developing students' intercultural skills.**

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INTRODUCTION

Engineering design plays a critical role in addressing social issues, such as the progression of climate change, the impact of global health emergencies (e.g., the COVID-19 pandemic), and advancing the UN's Sustainable Development Goals (SDGs). Engineering graduates entering the workforce should have skills to address these complex sociotechnical and global challenges,[1] which require attention and sensitivity to intercultural considerations.

To help students develop necessary intercultural design competencies, university programs commonly encourage participation in intercultural, immersive design project experiences, where students are directly exposed to design problem contexts and experience intercultural design dynamics first-hand, often framed as service-learning.[2] While these immersive design experiences have been shown to benefit students' abilities to incorporate aspects of complex design contexts into their design processes,[3,4] inadequately scaffolded design experiences may be counterproductive in the development of intercultural skills and actually reinforce pre-existing biases.[5]

Researchers have developed and validated methods to assess intercultural skills and abilities,[6,7] as well as theoretical frameworks to describe the maturity of students' conceptions of and interactions with diverse cultures,[8] but these methods have not yet been explored in the context of immersive design or service-learning. The ways students apply intercultural skills in these design experiences is unclear, as is the level of intercultural development during often short-term immersive and service-based design experiences. Additional qualitative research on student experiences with cultural differences has also been called for in a recent systematic review of international service-learning literature.[5] Therefore, this study explores the ways in which twenty-one engineering students applied and developed intercultural skills in service-learning experiences through reflective semi-structured interviews.

BACKGROUND

Given the global nature of the engineering profession, practitioners are expected to have intercultural understanding to work effectively in diverse national and cultural contexts.[9,10] For example, "cross-cultural humility" is cited as a key learning objective for engineering graduates and a core competency for practicing engineers;[1,11] engineers must understand the local socio-political context, the systems in which their work must fit, and the key relationships and stakeholders within these systems.[12] Intercultural skills can support engineers as they work within teams, engage with stakeholders, and frame design problems,[13-15] and are necessary to avoid systematic misalignment in design priorities between designers and other project stakeholders.[16]

Commonly, engineering education institutions encourage students to engage in design projects across diverse cultural settings.[2] These immersive design experiences, often with a focus on service-learning, enable students to practice effective problem-solving in new social contexts[17] and practice direct interaction with stakeholders.[18] Students' consideration of social and broader issues in design increases when they are intentionally prompted to consider these issues throughout their design process.[18] Immersive experiences also enable students to gain *contextual competence*, i.e., the ability to identify constraints and impacts of environmental, social, cultural, political and other

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contexts.[4,19] Prior work suggests that engineering students prioritize information from domain experts compared to stakeholders within the context, e.g., partner organizations and end users,[21] and would benefit from pedagogical structures to assist with collecting stakeholder insights.[22] To address this imbalance, engineering educators often encourage and even require students to meet regularly with broader types of stakeholders to encourage their incorporation of additional perspectives.[23,24] While immersive experiences have also been shown to encourage students' awareness of broader considerations,[3] some research has found that without proper guidance, students may instead be reinforcing cultural biases and stereotypes.[5]

Scholars across disciplines have taken up the study of intercultural maturity to understand how collegiate educational opportunities can effectively prepare the future workforce.[11,25] Prior work suggests that introducing students to multiple cultural perspectives and providing appropriate support can help them move between initial and more advanced levels of intercultural maturity.[26] While terms are often used in overlapping ways (e.g., intercultural maturity, global competence, cross-cultural adaptation, and multiculturalism), we draw from multidisciplinary literature to conceptualize *intercultural maturity* as an individual's capability to understand and act and think in ways that are interculturally aware and considerate of cultural differences.[8,26] More specifically, the Developmental Model of Intercultural Maturity (DMIM) suggests that a greater capacity for intercultural maturity allows for a more complex and multifaceted understanding of cultural differences, for example by recognizing the ways in which power and privilege affect interactions with others. Unlike quantitative indices of cultural competencies, such as the Universality-Diversity Scale [27] or the Intercultural Development Inventory,[28] which require larger sample sizes, the DMIM is well-suited to exploratory, qualitative inquiry.[26]

While prior studies have explored how engineering students consider context in problem solving approaches within immersive design scenarios broadly,[20,29,30] with respect to social impact of engineering solutions,[31] and with respect to historical and political contexts in service-learning or humanitarian-based engineering,[32] researchers have not explored how students learn and adopt intercultural skills during immersive design experiences. While international research experiences have been shown to accelerate the development of intercultural maturity[33] compared to domestic experiences, it is not yet known how different aspects of immersive experiences contribute to students' intercultural maturity within design engineering.

METHODS

Research objectives

Our goals were to identify key elements at the intersection of design and intercultural skills among engineering students in immersive, service-learning design experiences. We asked the following research questions:

1. What qualities of intercultural maturity do engineering students demonstrate during immersive design experiences?
2. How might immersive design experiences impact the development of engineering students' intercultural maturity?

Data source

We collected data from 21 undergraduate and graduate (MS) engineering students at a large research university in the midwestern United States, which is consistent with sample sizes used in

comparable qualitative design interview studies[34] and meets sample size recommendation for saturation in qualitative research.[35] We identified participants through purposeful sampling,[36] representing diversity in students' immersive experiences (international and domestic), majors, and class standing. Recruitment emails were sent to students in experiential courses, co-curricular organizations, and study abroad programs. We particularly targeted those who had participated in intercultural immersive design experiences, i.e., educational experiences where students engage in a cultural context different from their own, such as a project-based design, capstone course, or service-learning experience. These experiences were often off-campus in the U.S. or abroad and lasted a semester or longer, but also included on-campus simulations where students were provided with prompts based on real-world design problems. Approximately 18 of the 21 participants engaged in projects related to addressing social inequities; most of which were focused on low-income contexts, both rural and urban.

Participants ranged from second-year undergraduate students to masters students and were roughly split between male and female. Approximately half (52%) identified as White, while 24% identified as Asian, and 12% as Black or Latina/o. Table I lists the participant identifiers used in this manuscript, gender, class standing when the interview took place, engineering major, type of design experience, and location and duration of their immersive experience. Specific locations are redacted to maintain participant anonymity.

TABLE I
PARTICIPANT INFORMATION

Parti-cipant ID	Participant Gender	Class Standing	Engineering Major	Design Project Location	Type of Design Experience	Approx. Duration of Design Experience (Mo.)
A	Female	Fourth year	Industrial & Operations	Asia	Co-curricular	4
B	Male	Second year	Aerospace	North America	Co-curricular	4
C*	Male	Fourth year	Mechanical	North America	Class-based	12
D	Male	Graduate (MS)	Construction & Management	North America	Co-curricular	4
E*	Female	Fourth year	Biomedical	North America	Class-based	4
F	Male	Fourth year	Biomedical	North America	Study abroad	4
G	Male	Second year	Chemical	North America	Class-based	4
H	Female	Fourth year	Civil	Central America and/or Caribbean	Co-curricular	<1
I*	Female	Fourth year	Mechanical	Sub-Saharan Africa	Class-based	2
J	Female	Fourth Year	Nuclear & Rad. Science	Sub-Saharan Africa	Class-based	2
K*	Female	Fifth year	Biomedical	Central America and/or Caribbean	Co-curricular	<1
L	Female	Graduate (MS)	Biomedical	Sub-Saharan Africa	Class-based	2
M	Female	Second year	Civil	Asia	Co-curricular	<1
N	Male	Fourth Year	Electrical	Central America and/or Caribbean	Class-based	<1
O	Female	Fourth year	Biomedical	Central America and/or Caribbean	Co-curricular	4
P	Female	Second year	Mechanical	Sub-Saharan Africa	Co-curricular	2
Q	Male	Fourth year	Mechanical	North America	Co-curricular	2
R*	Male	Fifth year	Unclassified	Asia	Class-based	2

Parti-cipant ID	Participant Gender	Class Standing	Engineering Major	Design Project Location	Type of Design Experience	Approx. Duration of Design Experience (Mo.)
S	Male	Third year	Aerospace	North America	Co-curricular	4
T	Male	Graduate (MS)	Energy Systems	North America	Co-curricular	12
U	Female	Fourth year	Mechanical	North America	Co-curricular	4

*Pilot participants

Data collection

The interview protocol was developed by the research team based on prior experiences in research, teaching, and leading design and intercultural programs, as well as informed by literature on context in engineering design and education. Our aim was to develop open-ended questions that would allow for students to describe their experiences and perceptions in-depth, as well as discuss how they considered and approached intercultural aspects in their design work. Interviews were conducted by the first author, who was a graduate student at the time, and an undergraduate assistant. We piloted the interview protocol with five students with diverse backgrounds and experiences, which resulted in minor revisions including the clarification of language and reordering of the question sequence, before conducting additional interviews. Due to the limited nature of the changes made to the protocol after the first five interviews, data were included in our analysis with the remaining 16 interviews. Table II provides the general flow of the interview and a selection of example interview questions.

TABLE II
OVERVIEW OF KEY QUESTIONS FROM 60-MINUTE SEMI-STRUCTURED INTERVIEW PROTOCOL

Experiences during immersive design projects:
- Think back to when you first entered/landed at the location of your intercultural experience. What were your first thoughts and feelings about the setting and the people?
- What did you know about the community or stakeholders prior to that first encounter? Describe the partnership or relationships you had with the community or stakeholders.

Exploring design activities:
- What was your specific role in the design experience? What were your responsibilities?
- What obstacles or challenges did you face during the design process? How did you address them?
- How would you explain to someone else what it means to design?

Changes in intercultural maturity:
- How do you think your intercultural experience influenced your design experience?
- How would you describe the meaning of "understanding cultural context" when designing?
- What advice would you give to someone who might pursue a design in an unfamiliar cultural context?

We conducted in-person, 60-minute, semi-structured interviews with each participant. All interviews were audio recorded and transcribed. At the start of each interview, we asked participants to select and describe one significant intercultural design experience to guide their responses. We encouraged participants to be as descriptive as possible and guided responses towards eliciting rich descriptions of their intercultural experiences as well as deep reflections on conceptualizations and approaches to and conceptions of the design work.

Data analysis

Data analysis was conducted by open coding of the data, where we inductively defined codes through interpretations made during detailed readings of raw data.[36,37] In our first phase of data analysis, we used open coding procedures and coded excerpts that represented students' conceptions at the intersections of intercultural and design experiences. Through this process we identified the first set of emerging themes such as "invested in the experience" and "uncertain of collaborating." This initial set of themes provided insight to how students reacted to and conceptualized their immersive intercultural design experiences. Axial coding was then used to compare and refine themes across transcripts and excerpts. For example, excerpts coded around the theme of collaboration were further analyzed to identify the multiple ways in which students described their collaboration with diverse stakeholders. Excerpts within clusters were reviewed, and themes were identified. To answer our first research question regarding the qualities of intercultural maturity that engineering students demonstrated, we then summarized and synthesized key patterns along the continuum of intercultural maturity, including participant experiences and reflections. To answer our second research question regarding how immersive design experiences impact the development of engineering students' intercultural maturity, we conducted a separate, iterative thematic analysis to identify patterns related to design activities and students' intercultural maturity development.

We acknowledge that the experiences, expertise, and identities of the research team can influence the analysis. For example, while some of the researchers on our team had more experience with international and global education, others had greater familiarity with domestic student experiences. Additionally, some authors had experiences as international development practitioners, and others as administrators and participants of student service-learning experiences both inside and outside of academic contexts. To help leverage these complementary experiences and perspectives, as well as to standardize our approach, our analysis was guided by the DMIM, which provided a lens to understand design experiences and has been shown to be an effective framework for interview instruments in higher education.[38,39,40] The characterization of intercultural behaviors and reflection offered by the DMIM, which describes the outward behavior and internal perspective and cognition of students across different levels of intercultural maturity, gave us language and structure to develop and reach consensus on our codes. The first author led the primary coding of all transcripts, and the second author was responsible for an independent secondary coding effort to organize the data in the themes and patterns discussed in our findings. To further mitigate potential biases, at each stage of analysis research team members met periodically to review individual codes, analyze the assigned themes and variations within them, and develop a consensus around analyses and findings. Relatedly, we acknowledge that our research team does not include many of the identities and experiences of service-learning project participants from low- and middle-income countries, nor from low-income backgrounds in North America. We recognize that this study is limited to our perspectives as educators, practitioners, and students at a university in a high-income context.

RESULTS

We found that evidence of students' conceptions and use of intercultural design skills fell into two broad themes: 1) intercultural experiences, or how students directly or indirectly interacted with different cultural identities than their own, and 2) reflections on intercultural experiences, or

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students' reported awareness and consideration of intercultural skills in design, which students often reported as caused by their intercultural experiences and have been cited as critical to service-learning.[41] Within each theme, our analysis identified three sub-themes, which are detailed in Figure 1.

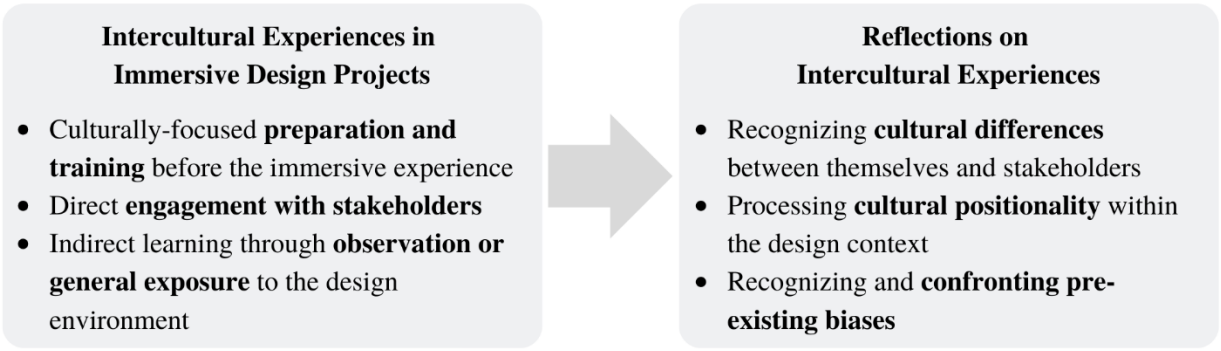

FIGURE 1
STUDENT EXPERIENCES DURING IMMERSIVE DESIGN PROJECTS AND SUBSEQUENT REFLECTIONS.

Representative examples of students' most reported patterns of intercultural experiences during immersive design projects and resulting reflections are summarized in Table III and detailed in the remainder of this section. Of the 21 participants, 19 reported one or more of the patterns of experience and resulting reflections.

TABLE III
FREQUENCY OF PATTERNS OF INTERCULTURAL EXPERIENCES AND RESULTING REFLECTIONS

Pattern Description	Count of Participants Who Reported Pattern
1. Direct engagement with stakeholders led students to recognize cultural differences	11
2. General exposure to the design environment led students to recognize their cultural positionality within the design context	10
3. Intercultural experiences in immersive design projects led students to reflect across multiple areas including cultural differences, cultural positionality, and/or biases	8
4. General exposure to design environments led students to recognize and confront their biases	3

Pattern 1. Direct engagement with stakeholders led students to recognize cultural differences

In our interviews with 11 of the 21 participants, students discussed new recognition of cultural differences as a result of their design experiences. For example, Participant K, a biomedical engineering fifth-year student, visited a Central American country to identify the needs and develop a relationship with a community clinic. She described sitting in the afternoons with community members to talk about both the project and the experiences of the people. Participant K describes getting to know the stakeholders and their perspectives:

> Another thing that's huge [here] was the revolution and historical political stuff…when talking with the people it came up in daily conversation all the time and the impact of that

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> in their daily life. All of those factors go into a technology and whether or not it's appropriate given the context. (Participant K)

In this case, direct engagement with project stakeholders enabled Participant K to develop a level of understanding of a cultural context different from her own, which she predicts may have implications for design. Similarly, direct communication with stakeholders in a Central American country led Participant H to reframe her design process around local perspectives rather automatically impose her team's own cultural frame of reference on design problems and solutions:

> Usually, our team had been going about it by looking at it from a solution standpoint, and so we were looking at, "Oh they need clean water. The biosand filter will work," and then we'd go and build it. What we found is like they are not automatically going to use the biosand filter because it might not actually be what they want, and so this year what we are trying to do is […] letting them tell us that. Like it's totally restructuring our whole design process. (Participant H)

Pattern 2. General exposure to the design environment led students to recognize their cultural positionality within the design context

Ten participants explicitly discussed a new recognition of how their background influenced their understanding of their own cultural perspectives (i.e., their cultural positionality). Participant Q, a fourth-year mechanical engineering student, reflected on his summer internship at a manufacturing plant in North America. When he started his position, he observed the division between engineers and those who worked on the manufacturing line.

> Most of the time the folks who worked on the line… didn't necessarily graduate high school. This is [an urban area] where education really isn't the best; graduation rates are not as high as they should be. A lot of the people who are salary folks compared to the labor union assembly line folks, they had their educations, they had their privileges along the lines of, "I drive car X, I'm getting paid this amount; I'm sitting here at a desk and you're standing out there at a line, you know, putting stuff together. I'm an engineer and you're a line worker." I've heard that directly. (Participant Q)

While Participant Q was excited to join a professional environment and gain experience in the workplace, he quickly realized cultural differences among employees from distinct educational and socioeconomic backgrounds. During his time with the company, union labor workers were on strike, which also heightened tensions. Participant Q shared feeling fortunate to have a mentor and supervisor who openly discussed the dynamics and who reminded him to value everyone. His supervisor once told him, "Hey, make sure you respect those line folks because they're the ones building the product and if they don't do their job then we can't do our job." As another example, exposure to the design context caused Participant U to discover that her assumptions that construction materials would be distributed in a similar way in Central America and the U.S. were invalid:

> Finding the materials that we wanted - it's really different than going to [a hardware store in the U.S.] and finding everything in one place. I can remember clearly, we couldn't find the right rods for one of our shafts, so we had to improvise. We used the heads of

> broomsticks that were pretty much the same size […], so that was definitely a challenge. (Participant U)

Pattern 3. Intercultural experiences in immersive design projects led students to reflect across multiple areas including cultural differences, cultural positionality, and/or biases

In eight cases, participants discussed two or more areas of reflection from among the categories described previously: recognizing cultural differences, processing cultural positionality, and recognizing and confronting pre-existing biases. For example, Participant I, a fourth-year mechanical engineering student, described her experience visiting obstetrics and gynecology departments at hospitals in a Sub-Saharan African country where she conducted observations for her senior project, as well as engaging with multiple stakeholders: "...taking as much time to talk to as many people as you can in the culture so you get ... representative samples." Participant I discussed her process of coming to understand differences in work culture between the U.S. and her project's context, as well as coming to recognize her cultural positionality towards the understanding of time and efficiency and her pre-existing biases other ways of thinking:

> One of the hardest parts was realizing that I was looking at things from my American culture perspective. It took me a while to think, "It's not wrong that they're doing it slow. It's just different." I'd say that's one of the biggest parts of cultural context is not only immersing yourself in their culture but knowing how your culture is interacting with your interpretation of them. (Participant I)

Participant T, a M.S. student in energy systems, discussed similar reflections based on her experience in her project environment in a Central American country. She identified herself as a woman who had experienced disadvantages in engineering settings while also acknowledging her privileged position as a white engineer from a high-income country.

> When I'm walking around, quite frankly, I'm a white female. It doesn't matter how much intercultural knowledge I have. I'm an American white female...I think on the flip side, there is a lot of, I think, oppression of women within [this nation's] culture. It's pretty patriarchal, so I saw a lot of these glimmers of hope, but it's definitely a patriarchal society, and that definitely rubs me the wrong way. Especially with doing engineering work, I'm just as capable as any of my male counterparts, but it was the males who would talk to the guy students that we would have, and it was very interesting dynamics, so that was certainly different than what I am used to or I believe. (Participant T)

Participant T reflected on her positionality as a woman in engineering within this new context, which she saw as 'pretty patriarchal' and more oppressive than her experiences in the U.S. Participant T expressed her tensions in reflecting about U.S. and global structures that have at times provided her with privilege and other times have not. Her experience in Central America gave her the opportunity to consider and work through her own positionality in these local and global contexts, which led her to consider appropriate approaches for how to design and work in that environment. At the same time, Participant T described her personal approach to design, reflecting on recognition of humility in her competencies as an engineering student:

> There's a lot of people in those villages that have been welding for all their life, or they've been doing car mechanic stuff all their life. As engineering students, we don't know that practice kind of thing, so I was definitely looking forward to learning that. (Participant T)

Pattern 4. General exposure to the design environment led students to recognize and confront their biases

In three cases, participants described recognizing, and to some extent confronting, their own biases as a result of their immersive project work. Participant A, a fourth-year industrial and operations engineering student, stated that she used to think she needed to go outside of the U.S. for an immersive intercultural opportunity – until she had an immersive design experience in a high-poverty urban area where she worked on a project addressing issues in a low-income neighborhood. Part of her team's design process required identifying community needs and developing appropriate structures through direct engagement with community members. This engagement led Participant A to reflect on pre-existing biases she had to confront during the project, which included judgements related to race and class:

> When we canvassed, I was nervous. I think it was fine after we started talking to people. We noticed that not everyone is out to get you. There are, I don't know, some abandoned houses and some people that are probably up to some sketchy things but there's a lot of people who are not. I think once we started talking to people who were involved and invested, that was fine. (Participant A)

While it is not clear that Participant A has completely worked through her biases as a result of this design experience, she has started to recognize her reflections as biases due to her engagement with stakeholders and general exposure to the design environment. In another case, Participant R, a fifth-year engineering student, traveled to a regional capital city in a Sub-Saharan African country for a summer-long, project-based course in a hospital. He reflected on his expectations based on the culturally focused preparation for his trip:

> I watched a documentary on a few particular cultural things, it focused mostly on technology there and how technology got introduced, [and] some of the weird, cultural things. Some of the stuff [our professor] gave us was more textbook: just visitors' guides and some landmarks to hit, and a little bit of their history, their economy… (Participant R)

Participant R's reflection on his pre-trip perspective and preparatory cultural training demonstrates bias and potential prejudice towards a "weird" foreign culture. Yet, after he was exposed to the design environment, he demonstrated growth in the maturity of his conceptions:

> [The city is] similar to other cities that I've been in. You went to the gas station to fill up and get water and snacks. We went to the hotel, we looked at big, nice buildings and monuments on the way there. (Participant R)

DISCUSSION

Cultural humility and adaptability as important precursors for developing intercultural maturity

Our findings provide evidence that intercultural design experiences help "move the needle" on students' preparedness as global engineers, though the extent to which a single design experience improves preparedness varies between individuals and is limited, in line with findings from prior research.[42] Although literature already suggests that engineering students who engage in international experiences are likely to improve their ability to function effectively across cultures,[43,44] we discovered trends that related to students' advancement in these areas including existing levels of cultural humility, adaptiveness, and exposure to mentorship.

First, we postulate that students who entered a design experience with cultural humility, i.e., prioritizing the development of mutual respect among individuals with different backgrounds and experiences, were able to learn more and advance their intercultural skills compared to students who demonstrated less cultural humility. Cultural humility is regularly advocated for in engineering and design spaces,[45] as are the positive attitudes and effective engagement with stakeholders that are likely to emerge when cultural humility is shown.[46] Literature suggests that students who are raised and educated in the U.S. may be less likely to exhibit cultural humility when engaging with individuals raised and educated in other parts of the world.[47] Engineering education environments have also been found to hold related stereotypes and implicit biases.[48] Our data align with these prior findings, suggesting that engineering students are bringing stereotypes, such as U.S. and engineering exceptionalism, with them in immersive experiences. The students who displayed biased assumptions about the superiority of their own context and perspective often did so by sharing their surprise when they observed that other contexts were more "developed," or that individuals were more capable, than they had expected. While some students expressed the value of learning from multiple perspectives, they may have still described a "right way" to think or behave. Bringing in and holding on to these biases appears to stifle the development of intercultural skills.

However, other students described more sophisticated levels of cultural humility, emphasizing relationship development, engagement with stakeholders in the decision-making process, and reflecting on their own limitations of their specific worldview. These characteristics of cultural humility, sometimes described as both an awareness of the value of other's perspectives coupled with an awareness of one's own limitations,[49] led students in our study to be more open to necessary stakeholder input and contextual information during their design processes. Thus, in addition to advancing in their intercultural maturity, students were likely better able to execute their intended engineering methods and design goals successfully.

Developing and applying cultural humility in design contexts takes time and experience, which is highlighted by the reflections of students in our study. For example, Participant I actively worked to identify that her frustrations with the pace of the projects was due to her "American cultural perspective." Furthermore, Participant Q's comment about "poor education" in a region of North America, while stepping towards cultural humility, falls short as Participant Q is still potentially seeing himself as higher than those with less formal education. It is important to note that Participant Q's experience and perspective is not unique. A prior study of engineering students at a U.S.-based university revealed that 56% of males and 31% of females demonstrated the lowest levels of intercultural sensitivity, denied the existence of cultural differences, and saw other cultures as inferior.[50] In addition, confronting biases was reported by a minority of participants, potentially indicating that it is a difficult task for students that may require targeted support by educators if students are to approach design with cultural humility.

Though all students in our study reflected on interpersonal challenges while working across cultures, our findings suggest that students who were able to adapt were more likely to advance their intercultural skills and maturity. For example, when assumptions were challenged, some students demonstrated flexibility, changing the project scope or target users. In other cases, however, students did not change their approaches and continued to design based on their original assumptions without compromising or adapting. In the latter case, students missed opportunities to develop their abilities to incorporate stakeholder perspectives and contextual factors, and ultimately advance their intercultural skills.

Four educational outcomes of immersive intercultural design experiences

Our findings suggest four main educational benefits from immersive intercultural design experiences: (1) enabling student engagement with design contexts and stakeholders from cultural backgrounds students had not previously encountered, (2) increasing motivation to consider impacts in design by placing students closer to perceived social impacts, (3) enabling mentorship by individuals with expertise on the project context, and (4) creating complimentary educational opportunities through preparation for, and general exposure to, the design environment in addition to actual design activities. Each of these benefits are described, below.

Engaging with new cultures, people, and design contexts: Design can encourage engagement among students, diverse groups of people, and places in ways that may not occur otherwise, exposing students to new perspectives and experiences that may prompt reflection and growth. This benefit is demonstrated by Participant K's realization of the differences between U.S. and Central American medical contexts through discussions with medical practitioners, as well as Participant A's increasing, but still limited, comfort in low-income neighborhoods in North America through engagement with residents.

Increasing student motivation to consider the impacts of their work: Another positive aspect of immersive design experiences may be increased motivation for students to engage with the implications of their work. Experiences of dissonance, such as those caused by interacting with different or contradictory perspectives through cross-cultural design, can motivate students to connect with the broader social and political implications of engineering,[51] which they may otherwise be shut off to or sheltered from. Highlighting the impact of engineering design may be particularly important for students who identify with a marginalized community because it allows them to more directly see the benefits of their work.

Mentorship by individuals with expertise in the project context: Students with close mentors in the design context were able to receive valuable feedback and advance their intercultural and design skills. These mentors acted as "cultural translators" for students, reminding them to embrace and respect differences. For example, Participant Q's mentor reminded Participant Q to respect people without the same levels of education. Although students reacted differently to their mentors' feedback, our findings suggest that frequent mentorship with individuals within or deeply familiar with the design context may help students better process and reflect on cultural differences.

Creating synergy across educational opportunities: The multiple types of cultural experiences within immersive design, such as preparation before a project starts, direct stakeholder engagement, and general observation and exposure to design environments offer a synergistic and multi-dimensional learning opportunity for students to grow in their intercultural maturity. For example, Participant R described clear biases after preparation for his trip to a Sub-Saharan African country, but as a result of his exposure to the design environment and engagement with stakeholders, he admitted to having the wrong impression; a potential advantage of immersive design over classroom experiences.

Potential neutral or negative impacts of immersive design experiences

When stereotypes and prejudice are not explicitly addressed in immersive design and service-learning in engineering, there is a risk that preconceptions may be reinforced rather than dispelled,[5] potentially with uncertain or negative impact on students' intercultural maturity and the communities they work with.[52] For example, even though Participant A described a reduction in

her biases towards the culture of other project stakeholders at the beginning of her design project, her language indicates that, even in hindsight, she still holds a level of bias towards the community in her project. It is not clear that she was provided with adequate support to work through her prejudices, nor is it clear that she left the design project without lasting and/or reinforced elements of bias.

It is also worth noting that most students did not express doubts about the appropriateness of engineering design as a primary framework for developing solutions to the problems of social inequity they were tasked with. This is despite the historical limitations and harm caused by engineering design in efforts to address social inequity,[52,53] in addition to the limited overlap between engineering design skills available to students in immersive design experiences and the full range of social and technical skills needed to solve the complex problems that students take on.[53] As such, our findings suggest that students would benefit from a more culturally-humble, historically contextualized approach to immersive engineering projects that may enable them to advance along the intercultural maturity continuum more effectively, while also reducing the likelihood of negative outcomes for participant communities.

Design has the power to challenge harmful power dynamics by amplifying and assigning value to the knowledge, experiences, and context of project stakeholders, ultimately increasing their self-efficacy. On the other hand, if design proceeds without prioritizing consideration of local problem contexts, it may instead waste resources and reinforce existing power inequities.[52] Though immersive design experiences may help students learn how to apply intercultural skills to better incorporate information from previously unfamiliar stakeholders perspectives and design contexts, the short-term nature of most immersive design experiences means that there is limited opportunity for stakeholder engagement and/or limited continuity between student teams over time. This elevates the risk that students may exclude stakeholders, if inadvertently, and reinforce the harmful power dynamics that are especially common in intercultural design.[52] It is critical that these communities are not framed implicitly or explicitly as "classrooms" or "projects" for engineering students. While students may support and learn from project community members, communities must ultimately lead the long-term direction and outcomes of design work if it is to benefit both project participants and engineering students.

Limitations

This study discusses three elements of immersive design experiences that can influence students' intercultural maturity: pre-immersive training, immersive activities and structures, and post-reflective activities. We did not collect data during each stage, however, but only during a reflective interview after students' project experiences. Although students often discussed individual aspects of immersive design experiences (i.e., preparatory training, direct stakeholder engagement, or indirect exposure or observation) as affecting their perceptions, we were not able to discern which aspects of their experiences were affecting their responses to interview prompts, nor were we aiming to discern possible impacts of prior personal or professional intercultural experiences. In this exploratory study, we did not attempt any quality assessment of participants' projects, so our analysis does not explicitly connect to any markers of design quality. Future research could investigate potential links between students' intercultural maturity and quality of their design outcomes, as well as the influence of specific aspects of immersive design experiences on their reflection and learning, to better inform immersive experience design.

CONCLUSION

In summary, our findings demonstrate that immersive intercultural design experiences encourage students to reflect and enable the development of intercultural skills in ways that may not otherwise be possible with traditional engineering pedagogy. Students in our study were regularly challenged to confront their biases and assumptions. Indeed, the way students responded to these interpersonal challenges (e.g., exhibiting high or low cultural humility, displaying adaptability or rigidity) had a clear impact on their experience and outcomes. Significantly, these findings do not suggest that intercultural design experiences on their own ensure adequate preparation for professional engineering design in intercultural contexts; students that travel abroad once or twice are not necessarily competent in these ways. Rather, students who demonstrated higher levels of cultural humility and a willingness to adapt, especially when guided closely by a mentor, were more likely to advance their intercultural maturity during immersive design experiences.

As such, pre-immersion training is a critical component to student success. Training that emphasizes cultural humility practices, sets expectations, and encourages flexibility in moments of uncertainty is likely to improve student outcomes. Students enter into projects with a range of intercultural skills, and educators should meet students where they are, while providing multiple opportunities for advancement.

Most notably, this study highlights the importance of encouraging cultural humility among students working on intercultural engineering design projects. Demonstrating cultural humility by developing relationships and incorporating the feedback and ideas of other stakeholders is not emphasized in engineering education and is not easily achieved, especially when students and other stakeholders do not have comparable cultural backgrounds, formal educations, and social statuses. It takes time to get to know stakeholders, build social relationships, and acknowledge stakeholder's contributions and expertise. Our findings highlight the importance of these skills in engineering design in intercultural settings.

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