Mapping Student Development in Culturally Contextualized Design

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Abstract

Culturally contextualized design (CCD) merges two areas of study—the processes by which engineers improve as designers and student development theory for intercultural awareness. Derived from empirical data collected from thirty-five student interviews, we developed a conceptual framework for CCD progression. The Culturally Contextualized Design framework represents three levels of sophistication – novice, aware, and informed – for each of the five CCD aspects: (1) human-centered, (2) collaborative, (3) intentional, (4) open to flexibility and ambiguity, and (5) invested and committed. The goal of this paper is to present the examples of three engineering students with different backgrounds and experiences and to map their development within the framework. We also discuss the potential utility of this new framework to understand how engineering students learn to integrate culture and design and to assess the impact of educational practices.

Introduction and Background

Experts consistently point to the importance of developing the T-Shaped student—the engineering student with deep technical knowledge and the intellectual breadth to work across disciplines and settings.[1,2,3,4] In addition, the Accreditation Board for Engineering and Technology emphasizes that engineering education must prepare students with "the ability to understand the impact of engineering solutions in global, economic, environmental, and societal context."[2] Thus, a successful engineering education should prepare students to be designers who appreciate the cultural contexts of design stakeholders and to integrate this knowledge into design decisions.

We use the term *culturally contextualized design* to describe this process of creating culturally relevant, user-centered engineering design solutions. Culturally contextualized design merges two areas of study—the processes by which engineers improve as designers[5,10] and student development theory for intercultural awareness. As more engineering colleges are emphasizing cultural knowledge in addition to technical skills,[6] engineering students are becoming more engaged in study abroad and service-learning programs. As a result, tools have been developed to assess the intercultural competence of engineering students.[7,8,9] Our intention is to synthesize and expand on existing efforts that align engineering design and intercultural development.

The literature on design alone is broad and extensive. The design process has been particularly well recorded and varying models have been developed. For example, Crismond and Adams[5] present a robust matrix illustrating the design learning trajectories of K-16 students. Their matrix derives from existing literature and explores nine design strategies, from "understanding the challenge" to "reflecting on the process." Compared to beginners, informed designers are described as continual learners who work creatively and make decisions based on their skills and knowledge. Similarly, Cross[10] compares the behaviors of expert and novice engineering designers. For instance, when solving a problem, expert designers focus on "breadth-first approaches" compared to "depth-first approaches," which are adopted by novice designers.

Existing empirical work helps us understand the behavioral differences of designers as they progress from novices to more informed designers, and then to expert practitioners.[11,12]

Our understanding of design continues to evolve as engineering students engage in multi-disciplinary activities. Multi-disciplinary design projects challenge students not only in understanding design processes, but also in learning to work with people from diverse backgrounds, engaging in human-centered design, remaining open to constant change, and becoming passionate and committed to a project.[13,14] The integration of multiple disciplines, not to mention the synthesis of two distinct developmental processes, have long been perceived as a difficult task.[15] Nonetheless, this intersection of engineering design and intercultural learning and development is the focus of our work. Grounded in human development[16] and intercultural sensitivity theories,[17] we link King and Baxter Magolda's[18] multidimensional Intercultural Maturity (ICM) model to existing literature on engineering design learning. The ICM model highlights students' competence in navigating intercultural interactions and presents three levels of maturity across the cognitive, intrapersonal, and interpersonal domains. In this model, students classified in the "initial level" report being threatened or becoming immobilized when encountering difference. The "intermediate level" student struggles with difference, but is open to learning and asking questions. Finally, the "mature" student reveals a level of self-reflection and openness to difference.

A developed designer integrates cultural and design knowledge to understand the user and the context of the design environment. Contextual design has been studied for decades, focusing on how the economics, ecology, and environment are incorporated in design decisions.[19] Green, Linsey, Seepersad, and Wood[20] define *context* as "the circumstances and setting in which an object occurs, and which influence its value." Their findings suggest that contextual design is challenging and complex, especially when attempting to learn about the user and the user's environment. Additionally, Kilgore, Atman, Yasuhara, Barker, and Morozov emphasize the need for designers to simultaneously shift from local and global contexts in order to understand the impact of the design.[21] In an effort to measure students' contextual competence, Merson, Lattuca, and Terenzini[22] developed a scale of five characteristics including the "ability to use what you know about different cultures, social values, or political systems in developing engineering solutions." Our intention is to synthesize and expand on these existing efforts to align engineering design and intercultural development.

Research Design

This paper focuses on examples of individual students' experiences and their conceptual progressions in culturally contextualized design. We provide an analysis of three student experiences as an example of how student insights guided the development of our conceptual framework. Alongside student experiences, we acknowledge that prior research has captured elements of our framework, and therefore, both existing literature and our findings create a robust understanding of culturally contextualized design.

Participants

As part of a larger framework development project, we collected data from thirty-five undergraduate and graduate engineering students at a large midwestern research university (for an analysis of all thirty-five interviews and a detailed description of the framework development see article in review[23]). We identified participants through purposeful sampling[24] to ensure diversity in student backgrounds and experiences. Here, we selected three students from this larger set to represent diverse backgrounds, types of experience, and levels of culturally contextualized design sophistication. Background information on the three participants is provided in Table 1. We replaced their names with pseudonyms.

Table 1: Three Student Examples

Student Name	*Concentration*	*Year*	*Gender*	*Type of Experience*
Julia	Mechanical	First Year	Female	On campus semester course
Richard	Aerospace	Third Year	Male	On campus semester lab
Hayley	Civil	Fourth Year	Female	One-week international trip

Data Collection

Through semi-structured interviews, we asked participants to share their culturally contextualized design experiences, capturing a range of experiences both on and off campus as well as domestic and international. At the beginning of each interview we prompted participants to reflect on their intercultural and design experiences and asked them to select their single most significant intercultural design experience. We also gave them the option of selecting two experiences, one intercultural and one design experience, as long as the intercultural experience occurred prior to the design experience (see Figure 1). The interview protocol consisted of three parts: intercultural interactions, design techniques, and the intersection between the two. Interviews lasted approximately one hour. Table 2 provides the general flow of the interview and some example interview questions.

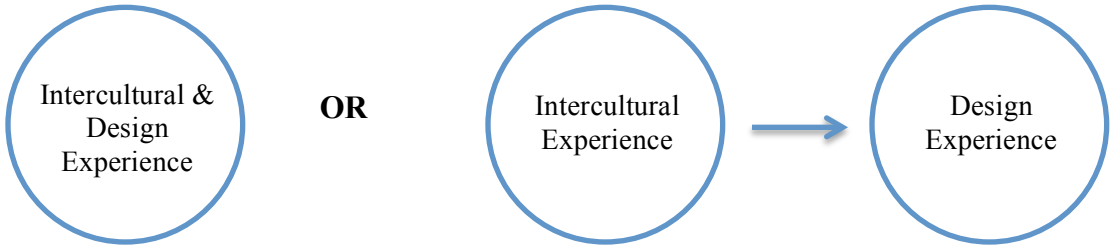

Figure 1: Prompt in Preparation for Interview

Table 2: Example Questions from Interview Protocol

Intercultural Interactions	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?
Design Techniques	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?
Intersection (Culturally Contextualized Design)	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?

Data Analysis

We adopted a grounded theory approach to identify emerging themes and to allow for our data to guide our framework development.[25] This resulted in a framework that represents three levels of sophistication (novice, aware, and informed) and five aspects (human-centered, collaborative, intentional, open to flexibility and ambiguity, and invested and committed) of culturally contextualized design (see Table 3 at the end of this paper). We mapped the students' development to the CCD framework and compared the students' positions relative to each other.

Findings

This section focuses on three student participants: Julia, Richard and Hayley. Julia is a first year mechanical engineering student. Prior to her first-year of college, she engaged in a university summer program designed to prepare students for degrees in science, technology, engineering, and mathematics. Julia identified this experience as her most significant intercultural and design experience given the program's goal to "combine technical expertise and global competencies." When asked to describe her understanding of cultural context when designing, Julia provided the following example:

> "…I may know [a design approach] which is really complex and really sophisticated. Someone who comes from just like a regular public high school may not have had that higher-level education. They may think of something simpler which is actually a better design for our product, but I guess just because you come from different places you develop different ideas." (Julia)

Richard is a third year aerospace engineering student who identified his most significant experience at an aerospace lab course. Along with his team, Richard designed, built, and presented the team product to the rest of the class at the end of the semester. When asked to describe the meaning of cultural context when designing, Richard replied:

> "Having a good knowledge of other people's culture helps you relate and understand…I lived in Mexico for a portion of my life. When one of the girls [in my team] was talking, sometimes she was hard to understand, so I could kind of help if there was any confusion in something technical she was trying to understand because I understood her broken English a little bit better." (Richard)

Hayley is a fourth year civil engineering student. As a two-year member of a student organization, Hayley had the opportunity to participate in a one-week trip to Jamaica, where they design and built biosand filters for the host community.

> "Usually our team had been going about it by looking at [the project] 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 [the people in the community] are not automatically going to use the biosand filter because it might not actually be what they want, and so this year we are trying to take a step back and learn about their culture and their daily habits." (Hayley)

There is a clear differentiation among these three students in how they articulate their understanding of design in a cultural context.

Mapping the Student Examples to the CCD Framework

This section summarizes the elements of the CCD framework and explains how our three students map to particular levels of sophistication.

Human-Centered

In the context of our framework, *human-centered* is the desire to understand the cultural context of stakeholders in order to identify their needs and to thoughtfully carry on the design process.

The first level of sophistication, *novice*, describes a designer who has vague or no knowledge of the stakeholders' cultural backgrounds and is unable to understand their cultural values, settings, or needs. This designer focuses on technical aspects of the design and on personal assumptions of what is right and wrong. Julia, for example, described her experience when entering and interacting in a new cultural environment while designing.

> "I was slightly freaked out [walking into the group] just because I wasn't used to having so much culture. I'm not really from a cultural family. It was just like everyone is from all of these places and I'm from a [State]. I felt really, I don't know, uncultured in a way when I came in." (Julia)

Coming from a homogenous community, Julia expressed her lack of experience interacting with people who are different. She also demonstrated a lack of understanding for her own culture and the culture of others.

In the *aware* human-centered level, efforts to understand the lives and experiences of stakeholders are typically attempted through second-hand or indirect avenues. At this level, designers lack the ability to empathize and engage with users to increase the likelihood that the stakeholders' needs are met. The *informed* human-centered sophistication level differs in that the designer becomes immersed in the lives and environments of numerous stakeholders to understand the complexities of the social, historical, and political cultural context. In addition, the informed designer engages in deep listening and empathy to identify and address the stakeholders' interests and needs. Throughout his interview, Richard used language that might have placed him in the informed sophistication level. However, while using the appropriate language, Richard seemed to lack the necessary personal experience.

> "I think having a good knowledge of other people's culture helps you relate and understand…If you can empathize with people you can better understand them and better relate to them. If you can relate to somebody, you can solve the problem. I definitely think it's important, but I don't know how to describe why." (Richard)

While Richard's description of a *human-centered* experience mapped to an aware level, Hayley represents an informed designer.

> "When you have a design, before you even get to the design, there's a lot of work that goes into it. I think if you are designing for any other culture, first you really need to do research, and you need to learn about their daily lives. You need to learn about what factors affect their daily lives. Maybe it's government or economics or gender roles or anything. I think that kind of getting it down to the human level is really important, and then from there just trying to always keep that culture in your mind as you are designing. It's really hard, but don't design it for yourself. Just design it for them." (Hayley)

Hayley was not only aware of the stakeholders' daily lives, but was also cognizant of larger societal issues that may impact her design. At the same time, Hayley acknowledged the challenge and the importance to engage in the lives of stakeholders.

Collaborative

The *collaborative* characteristic of culturally contextualized design is the capacity to work and interact with stakeholders who have different perspectives during the design process. A *novice* designer acknowledges the value of diverse perspectives, but is not aware of the importance of collaborating with users. Ethnocentric views lead to a focus on the designer's engineering knowledge and a lack of conscious awareness of power imbalances across groups. Students may hear the stakeholders' opinions, but not consistently incorporate them into the design process. Julia, for example, was challenged by power dynamics when collaborating.

> "I think the hardest challenge was trying not to offend anybody because that's always really hard when you're in a group session with a lot of cultures. You don't want to say…my culture is better than your culture." (Julia)

A student in the *aware* level of sophistication is willing to engage with different others, but avoids judgment or conflict. There is a focus on stakeholders who are easily accessible and users are still typically excluded from the design process. A designer in this level begins to explore how power structures vary across social groups and how designed systems can play a role in these differences. An *informed* designer engages with numerous stakeholders during the design process to create collaborative ties and challenge power imbalances across these relationships. An informed designer also utilizes points of conflict to increase understanding across differences. Richard and Hayley exemplify aspects of the aware and the informed levels of sophistication. Richard for example has learned to be patient and to support the ideas of those who may feel "nervous or unsure" – challenging power imbalances.

> "Lots of patience, I've learned, is definitely big. Learning to understand when someone brings a new idea to the table and if they're nervous or unsure of themselves you really got to coax it out of them and it can be a good idea." (Richard)

Similarly, Hayley hoped to engage stakeholders in the design process. Nevertheless, she acknowledged the challenge of collaboration.

> "The biggest challenge was that we weren't really getting a lot of people involved with our projects. After we built the biosand filters, we wanted to train the nurses in how to use them. That also didn't work out because the clinic was not open on Fridays. We didn't realize that. It was little details like that that we did not anticipate." (Hayley)

Hayley's intentions illustrate her ability to plan for and value collaboration with stakeholders, even when those ties were unsuccessful.

Intentional

The *intentional* aspect speaks to the individual's motivation to participate and engage with the goals and objectives of the design, and their purpose in completing the design experience. A *novice* level student will approach their engineering task as a charity project and consider relationships with stakeholders as need/help based or a one-way flow of knowledge. This student will knowingly or unknowingly perpetuate existing social power structures. A student who is *aware* begins to explore their own motives for participation in a given design experience. The student learns from others about social inequalities with a desire to seek equality and develop mutual benefits with stakeholders. Finally, an *informed* student designer reflects on past experiences and thinks self-critically about their own motives. This student hopes to mitigate social power imbalances and develops mutual benefits with stakeholders by learning from previous experiences. Not all students interviewed reflected on their intentionality. When fulfilling a class requirement or program, intentionality is difficult to capture. Nevertheless, Hayley's reflections captured this idea.

> "I would have tried to find out who to contact ahead of time, and kind of talk to [stakeholders] more, and just give them a heads up or maybe send them materials ahead of time. And then when we [visit] it would be like a reinforcement of that topic. I think it would have been nicer to maybe publicize in the community like, 'Hey we are building these biosand filters. Please come check it out and come work with us, and we'll teach you how to build it and stuff.' We just didn't really know how to do that." (Hayley)

After the fact, Hayley could reflect self-critically on her engagement and intentionality when interacting with community members, potentially using this knowledge to improve future interactions.

Open to Flexibility & Ambiguity

The propensity to engage in unfamiliar interactions and leverage differing perspectives describes the *open to flexibility and ambiguity* aspect of culturally contextualized design. At a *novice* level of sophistication, a student feels threatened by different perspectives and attempts to highlight their own strengths. Additionally, the student links negative stereotypes with unfamiliar cultural values, behaviors, and settings. Julia portrayed some *novice* traits when focusing on her own ideas while working with diverse individuals.

> "I have a certain way of trying to get things done. When I approach a project I have it built by a certain time and then go about that. It was really a lot of conflicting ideas that people wouldn't try to justify their idea for themselves then you see like, 'I want to do this.' I'm like, 'Wanting is not the same as having a good idea.'" (Julia)

Julia's inability to embrace new ideas because she felt colleagues could not justify a "good idea" may have limited her learning. On the other hand, an *aware* culturally contextualized designer is willing to embrace ambiguity and take risks during the design process if prompted by authoritative claims. However, this type of student works towards achieving a "universal standard" and follows mainstream ways of approaching work. In contrast, *informed* students explore alternative perspectives and behaviors in a nonjudgmental way and without feeling threatened. They see value in situating the self in a different cultural context and engaging in unfamiliar interactions in order to expand understanding of engineering practices. Richard and Hayley both exemplified aspects of an informed designer. Richard became open and listened to new ideas when designing.

> "We had to make a little mechanism to put on the back of our craft so it could be launched and we had a really short period of time to do this. I was looking around, trying to figure out how we could cut something up and one of the girls grabbed a spare piece that we had and said, "we can just cut these off and glue it to the back," and I was like "Whoa, that is great!" (Richard)

Hayley also became open and creative when designing.

> "A lot of it is just being hands on. We are limited to a hammer and a drill and a saw. We don't have power tools. We don't use tools that are down in the Center. It's pretty much

> like what we can afford, which is nice. A lot was just making it up, trying it out, and seeing what worked and what did not work." (Hayley)

Richard and Hayley's ability to engage led them to learn new ideas and perspectives on how to design.

Invested & Committed

Our framework also highlights *invested and committed* student designers. In the context of our framework, this category captures personal commitment to social justice and the sustainability of the design and processes. At the *novice* sophistication level, a student approaches design as a singular task without intention to apply what has been learned to a new situation. An *aware* student has a developing sense of social responsibility and ethics. They begin to explore the impact of the design in the social, economic, and environmental context of the design space. After his experience, Richard developed a commitment to apply what he had learned.

> "I kind of took [what I had learned in my aerospace group] and I've been using that in my student organization to help create better and more fun group dynamics and get everyone's ideas and what everyone thinks." (Richard)

Hayley exemplified traits of an *informed* designer by questioning traditional engineering design approaches and dominant ideologies and by focusing on the needs of her particular stakeholders.

> "We've actually been doing biosand filters for a couple years. We have different versions each time. This year we wanted to make something small that you could transport if [the user] didn't like where we put it, they can put it wherever the heck they wanted it. Also, smaller because their homes aren't very big, so if we were to ever get these filters into somebody's house we wanted it small. As far as functionality, that was our goal. Then also, making sure that it actually worked." (Hayley)

An informed designer also reflects on their own contributions and advocates for social equality and sustainable impact. This type of student is a lifelong learner and applies lessons learned to new situations.

Discussion

Mapping the Student Examples to the Aspects of the CCD Framework

Julia's first intercultural experience happened in the context of design as she learned to interact and work with people from different backgrounds. Her *novice* experience was evident as she was "freaked out" when entering a new environment and struggled to be open to new ideas. Richard reflected on a semester-long aerospace lab group project where he had the opportunity to work with a diverse group and utilized his previous experiences while living in Mexico. As a well-intentioned individual, Richard demonstrated aware/informed characteristics that made him open to new ideas. Nevertheless, his lack of experience prevented him from fully immersing himself in unfamiliar situations and demonstrating a commitment to social justice in design. Hayley on

the other hand, displayed a commitment to learn and apply previous experiences to new situations. Her understanding of the daily lives of end users and her awareness of power structures allowed her to reflect on her intentions and closely collaborate with stakeholders.

These examples illustrate the varied levels of culturally contextualized design sophistication (see Figure 2). We use the term *culturally contextualized design* (CCD) to describe the process of creating culturally relevant engineering design solutions. A culturally contextualized designer is human-centered, collaborative, intentional, open to flexibility and ambiguity, and invested and committed. Hayley displayed more informed examples, while Julia shared more novice examples. Richard on the other hand moved between a novice and an informed designer. Consistent with design and intercultural studies, students vary in their development and may embody traits from across the sophistication levels.[12,18]

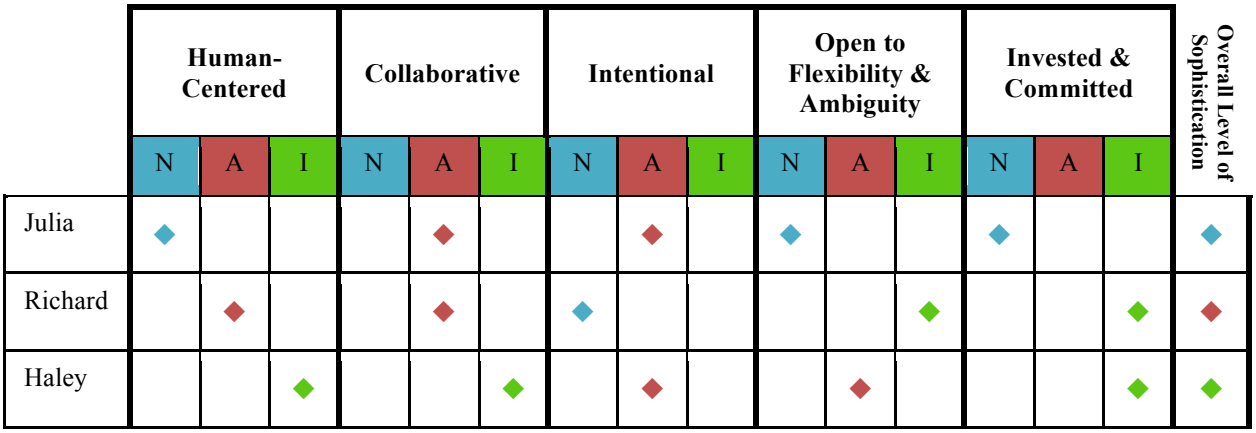

Figure 2: Mapping the Student Examples to the Aspects of the CCD Framework
Note: N=Novice, A=Aware, I=Informed

The three examples also demonstrate that students can be more or less advanced across culturally contextualized design qualities. For example, Richard was aware/informed in *human-centered* and *collaboration*, but less sophisticated in *intentionality* as his concepts represented an *aware/novice* understanding. Julia and Hayley were more consistent in their levels of sophistication among all of the aspects of CCD sophistication, *novice* and *informed* respectively.

Conclusion

The examples presented in this paper demonstrate how student descriptions and reflections on past experiences can be used to map their culturally contextualized design (CCD) sophistication. CCD development is difficult to measure, and there is not an easy-to-implement instrument to track students' levels or potential progress after a CCD experience. By combining existing literature and our own empirical data, we developed a framework to capture students' existing understandings and, eventually, to track growth. Our future studies will gather information from students both pre and post experience and investigate the extent to which our framework can help us understand the most effective types of educational experiences.

As we continue to test and refine the framework, we will consider how data collection methods impact student responses and levels of sophistication. By participating in our interviews, students were engaging in a structured, reflective process. We asked them to consider past design and intercultural experiences, and extracted meaning from those experiences. For some students, this may have been the first time they had consciously reflected on these experiences. Others may have already participated in a similar exercise. In either example, the interview experience itself plays a role in how students respond to questions and convey levels of sophistication.

This work also has implications for engineering education. The framework can help curricular and co-curricular programs hone in on particular aspects of CCD that might warrant greater attention. The examples highlight that students can progress at different paces according to different aspects of the CCD framework, and using the framework could help educators develop experiences that address all of the aspects of CCD. Finally, the framework is a step forward in assessing how students develop in particular learning environments.

By developing a way to assess students' CCD sophistication and potential growth, engineering educators will be better prepared to facilitate the development of engineers who can gather and apply cultural information in design decisions. Equally important, we can help the next generation of engineering students understand the long-term impact of their design work within broader global, economic, environmental, and social contexts.

Table 3: Culturally Contextualized Design Sophistication Among Engineering Students

	Human-Centered The desire to understand the cultural context of stakeholders in order to identify their needs and thoughtfully carry on the design process.	**Collaborative** The capacity to work and interact with stakeholders who have different perspectives during the design process.	**Intentional** The motive to participate and engage with the goals and objectives of the design, and the purpose to complete the design experience.	**Open to Flexibility & Ambiguity** The propensity to engage in unfamiliar interactions and leverage differing perspectives.	**Invested & Committed** The personal commitment to social justice and the sustainability of the design and processes.
Novice	Has vague or no knowledge of the stakeholders' cultural backgrounds and is unable to understand the cultural values, settings, or needs. Focuses on technical aspects of the design and on own assumptions of what is right and wrong.	Acknowledges the value of diverse perspectives, but not aware of the importance of collaborating with *users*. Ethnocentric views lead to a focus on own engineering knowledge and may not be conscious of power imbalances across groups.	Approaches the engineering design task as a charity project and considers relationship with stakeholders as need/help based or one-way flow of knowledge. Knowingly or unknowingly perpetuates existing social power structures.	Feels threatened by different perspectives and attempts to highlight own strengths. Links negative stereotypes with unfamiliar cultural values, behaviors, and settings.	Approaches design as a singular task without intention to apply what has been learned to a new situation.
Aware	Attempts to understand the lives and experiences of stakeholders, typically through second-hand or indirect sources. Lacks the ability to empathize and engage with users to increase the likelihood that the design meets the stakeholders' needs.	Willing to engage with people who are different but avoids judgment or conflict. Works with stakeholders who are accessible, typically excluding users from the design process. Begins to explore the ways systems impact power structures across social groups.	Begins to explore own motives for participating in design experience. Observes and learns from others about social inequalities with a desire to seek equality and develop mutual benefits with stakeholders.	Willing to embrace ambiguity and take risks during the design process if prompted by authoritative claims. Works towards achieving a "universal standard" and follows mainstream ways of approaching work.	Has a developing sense of social responsibility and ethics. Begins to explore the impact of the design in the social, economic, and environment.
Informed	Becomes immersed in the lives and environments of numerous stakeholders to understand the complexities of the social, historical, and political cultural context. Engages in deep listening and empathizes to identify and address the stakeholders' interests and needs.	Engages with numerous stakeholders during the design process to create collaborative ties. Challenges power imbalances across these relationships. Utilizes points of conflict to increase understanding across differences.	Reflects on past experiences and thinks self-critically about own motives. Hopes to mitigate against social power imbalances and develops mutual benefits with stakeholders by learning from previous experiences.	Explores alternative perspectives and behaviors in a nonjudgmental way and without feeling threatened. Sees value in situating self in a different cultural context and engaging in unfamiliar interactions in order to expand understanding of engineering practices.	Questions traditional engineering design approaches and dominant ideologies. Reflects on own contributions and advocates for social equality and sustainable impact. Is a lifelong learner and applies lessons learned to new situations.

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