AC 2011-1244: PHENOMENOGRAPHIC STUDY OF HUMAN-CENTERED DESIGN: EDUCATIONAL IMPLICATIONS

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Phenomenographic Study of Human-Centered Design: Educational Implications

Introduction

Design is a central and distinguishing activity of engineering[1] and one of the core criterion for evaluating and accrediting engineering programs[2]. Design is also a subject area that poses many challenges for faculty[3]. Incorporating human-centered design approaches--approaches in which designers have as a focus the people they are designing for--poses additional challenges. Not only do designers have to keep pace with the technology advances, they have to understand how the technology can be integrated in a way which keeps the needs of the stakeholders at a forefront, taking into account diverse social, cultural and ethical considerations. In today's globally competitive economy, it is more important than ever to develop effective design skills within the undergraduate years. However, before effective design learning experiences to develop the skills necessary for human-centered design can be created, an understanding of the ways in which students experience human-centered design is needed. This paper provides an overview of a phenomenographic study that explores students' understanding of human-centered design, presents the resulting outcomes space, and discusses the educational implications of the findings.

Motivation

Design has long been a core function of engineers, however, recently it has been argued that there is a paradigm shift occurring in design from "technology-centered design" to "human-centered design"[4]. Although it may be difficult to determine while in the midst of the paradigm shift that it is occurring, there is evidence from the number of "human-centered" design processes---processes that place high value on understanding the stakeholders in a very broad way and by including them as much as feasible during the design process---have emerged. Examples of these human-centered approaches include user-centered design, participatory design, contextual design, inclusive design, activity-centered design, use-centered design, practice-centered design, client-centered design, and empathic design. Leading design firms such as IDEO are also advocating human-centered design processes. According to Tim Brown, CEO and president of IDEO, in order for engineering graduates to make an impact in the global workforce, they must develop "design thinking". Brown[5] defines "design thinking" as:

> a methodology that imbues the full spectrum of innovation activities with a human-centered design ethos. By this I mean that innovation is powered by a thorough understanding, through direct observation, of what people want and need in their lives and what they like or dislike about the way particular products are made, packaged, marketed, sold, and supported. (p. 86)

Similarly, Dorst[6] argues that:

> Traditional design firms have lost their economic basis, and many have had to close down. But others have flourished, through working in a completely different way. They have learned to take a more pro-active role. They develop new product concepts in close concert with future users, and then offer these pre-designs to companies……this and

other new design approaches that are really changing the very nature of the design professions. (p. 8)

Although characterized by approaches with slightly different foci and philosophies, Zhang and Dong[7] summarized several definitions of "human-centered" design approaches to obtain the following five characteristics:

1. "The central place of human beings"
2. "Understanding people holistically"
3. "Multi-disciplinary collaboration"
4. "Involving users throughout the design process"
5. "Making products or services useful, usable, and desirable" (p. 3)

Similarly, Krippendorff[4] describes human-centered design methods as those that share the following three features:

1. **"They are design methods**, which entails that they systematically expand spaces of possibilities and then contract them to arguable proposals for artifacts that promise to bring forth desirable futures or prevent undesirable ones from occurring." (p. 230)
2. "**They are concerned with how stakeholders attribute meanings**. Because meanings are acquired in use, not designed, decisions on meaning ultimately cannot be taken away from those who are affected by a design, it stakeholders." (p. 230)
3. **"They render design proposals empirically testable,** at least in principle. Because a projected future cannot yet be observed, they provide arguments, demonstrations, if not tests for the projected reality of a design." (p. 230)

Utilizing human-centered design processes have been shown to increase productivity, improve quality, reduce errors, reduce training and support costs, improve people's acceptance of new products, enhance companies' reputations, increase user satisfaction and reduce development costs[8,9].

A critical part of design thinking and human-centered design is understanding the people affected by the design. However, there are many examples cited in the literature that point to a lack of understanding of the user or an understanding of the way in which the product would be used that contributed to its failure[8,10-11]. According to Damadaran[8]:

> Without effective user involvement in all stages of planning and design the organization is simply storing up problems for the future. When the problems emerge post-implementation they are likely to be serious and more intractable because system changes become more expensive as the design progresses and 'hardens'. (p. 365)

How is it, then, that engineering programs should go about developing "design thinking" and the skills needed for human-centered design? What experiences contribute most to the students' learning of human-centered design and the development of an understanding of the user and other stakeholders? As a first step to answering these questions, a phenomenographic study was conducted that explored the qualitatively different ways in which students understand and experience human-centered design. Understanding these variations is important in structuring appropriate and effective educational experiences. It is also needed before effectiveness of educational experiences can be determined. There are two specific aspects that are of particular

interest. First, how do students currently experience and understand human-centered design? Secondly, what are more comprehensive ways that students experience and understand human-centered design? Both aspects are important to understand, especially within the academic context. The first aspect is important because awareness of conceptions and misconceptions allows educators to build upon conceptions and target misconceptions[12]. The second aspect is important so as to know how to guide students in their journey towards more comprehensive ways of knowing. To address these needs, a phenomenographic study of students' ways of experiencing human-centered design in the context of "designing for others" was conducted. Students were recruited from a variety of design experiences including traditional design courses, service-learning design courses and experiences, internships, and co-ops. The research question which guided the study is as follows:

> What are the qualitatively different ways in which students experience and understand human-centered design in the context of "designing for others"?

A detailed description of the study is given in [13]. However, in order to understand the results of the study which provide the basis for the educational implications, an overview is provided here.

Research Approach

Because the goal of the study was to explore the qualitatively different ways in which students experience and understand human-centered design, a phenomenographic framework was chosen to guide the methodology of the study. Phenomenography has its roots in educational research in Sweden, arising from recognition that the qualitatively different ways in which learners experienced or understood a phenomenon were related to the qualitative differences in the outcome of that learning[14-15]. Phenomenography has been used to research and identify different ways of experiencing a wide variety of phenomenon from students' experience of learning object-oriented programming[16] to the quality of care in the psychiatric setting[17]. Related to design, phenomenography has been used to explore sustainable design[18], design students' experience of engagement and creativity[19], and the ways that design has been experienced by professionals in a variety of disciplines[20]. It should be noted that phenomenography is different from the more familiar qualitative approach, phenomenology. Phenomenographic studies seek to characterize the variation of the experience of the phenomenon, whereas phenomenological studies seek to characterize the essence of the experience of the phenomenon[21].

The outcomes of phenomenographic study are the categories of description and outcome space. Marton and Booth[22] state that within that outcome space, "The qualitatively different ways of experiencing a particular phenomenon, as a rule, form a hierarchy" (p. 125). This is based on the expectation that since the categories of description represent the relationship between the phenomenon and the person experiencing the phenomenon, the categories themselves should be logically connected through the experienced phenomenon[23].

Because the context of the experience is very important in understanding the experience itself, the phenomenographic study focused on the variation of students' experiences of human-centered design in the context of "designing for others". However, since the goal of the study was to study the variation of the ways of experiencing human-centered design in general, students were recruited from a variety of design experiences. This included design experiences

which used a service-learning pedagogy, such as Engineers Without Borders and Engineering World Health, as well as more traditional design courses, such as capstone courses and introductory design courses, and internships. Using maximum variation sampling[21,24], 33 participants were selected to maximize variability of experiences based on type, duration and client of the design experience and the student's major, academic year, sex and ethnicity. Five were first-year students, five were sophomores, seven were juniors, 15 were seniors, and one was a graduate student who participated in one of the undergraduate design courses. The students represented 18 different majors. Sixteen of the participants were female; 17 of the participants were male. Seven different ethnicities were reported by the students (free responses). Many of the students participated in multiple experiences in which they "designed for others." The number of semesters that the students participated in the course or activity ranged from one to five semesters.

The interview protocol was semi-structured and included questions that prompted students to reflect on their experiences with stakeholders and how they go about designing and creating a product that will meet the needs of the people for whom they are designing. The interviews began with the question, "Can you describe an experience you have had that involved designing for others, which I am calling "human-centered design"?", and included follow-up questions such as "How did you approach the task from its beginning to its current status?" and "How did you decide to do these things?" After all of the interviews had been completed and transcribed verbatim, analysis began by reading and re-reading the entire set of interviews. Analysis of the data in phenomenography is done at the level of the transcript, considering the transcript as a whole. Each transcript is considered within the context of all of the other transcripts and sorted into initial categories. Similarities and difference among the groups were described which served to help clarify and refine the categories. Several iterations of this process were completed. When the categories began to converge, analysis of the structural relationship between the categories began and continued until an outcome space that met the following criteria was found: 1) each category represented a distinct way of understanding the phenomenon, 2) the categories are logically related, and 3) the outcomes were parsimonious[22-23].

Validity and Reliability

Two types of validity checks, communicative and pragmatic validity, are common with phenomenographic studies. The communicative validity check requires being able to defend the results to the research community, as well as representatives of the research sample (although not the interviewees themselves). This was achieved by establishing a dialogue with the participants during the interviews, focusing on the transcripts as a whole, and by working with other researchers during the analysis. In phenomenography, reliability is ensured by detailing the interpretive steps of the study and presenting examples to illustrate those[23]. Those steps are included in the detailed version of the paper[13].

Findings

Analysis of the data yielded seven qualitatively different ways in which the students experienced human-centered design within the context of "designing for others". These different ways of understanding are referred to as categories of description. Each category reflects a qualitatively different way of understanding or experiencing human-centered design. Inclusion in the specific

category was based on the student designers' understanding of human-centered design as a whole as reflected in the experiences they shared in their interviews. The students themselves are not assigned to that category, but their experiences as described as part of the interview were assigned to the category. An overview of the categories of description is given in Table 1. In addition, the pseudonyms of the students whose experiences comprised that category are given.

Table 1. Categories of Description of Students' Experience of Human-Centered Design[13]

Category of Description (Human-Centered Design is...)	Summary
Category 1: Technology-Centered	Design is not human-centered, but technology-centered design. The focus of the design is on the technology and solving the technical problem, not on the "others" or humans. The approach lacks both an understanding of the users and an appreciation for the users' knowledge, experience, and perspective. (Joe, Emily, and Jacob)
Category 2: Service	Human-centered design is not design but service, helping or positively benefitting others but utilizing very limited, if any, design methods or processes to achieve that goal (e.g., needs assessment, iteration, decision-making tools, convergent and divergent thinking, balancing of constraints, perspective-taking, getting feedback, or prototyping). (Alisa, Craig, Julian, James and Clare)
Category 3: User as Information Source Input to Linear Process	Human-centered design is a linear design process where users and other stakeholders are viewed primarily as sources of information, assistance, and/or support, not those whose needs should be reflected in design. (Daniel, Kylie, Todd, Heather, and Brendan)
Category 4: Keeping the Users' Needs in Mind	Human-centered design is keeping the users' needs and how design will be used in mind while designing. This approach involves gathering information about the users primarily from higher level stakeholders or experts versus the users directly. Integrating that information with aspects of technical feasibility and viability is done to the extent that disciplinary knowledge allows. (Gina, Nishant, Ben, Andres, Aparna, and Megan)
Category 5: Understanding the Design in Context	Human-centered design is understanding the design in context, seeking knowledge not only about the stakeholders' needs and how the design be used, but also more broadly the social, political and/or environmental context. (Chloe, Salena, Amelie, Krista, and Michael)
Category 6: Commitment to Involving Stakeholders to Understand Perspectives	Human-centered design is a commitment to involving stakeholders in the design process to understand their perspectives, seeking and taking into consideration contextual information and balancing multiple perspectives. (Andrew, Sejal, Ethan, Ava, and Paige)
Category 7:	Human-centered design is Empathic Design, basing design on knowledge

Empathic Design	gained through a connection with end users, not on preconceived ideas and assumptions. A very broad understanding of stakeholders is developed beyond scope of project by interacting with users informally and in social situations. (William, Maddie, Greg, and David)

The seven categories of description resulting from the study formed an outcome space that was two-dimensional with distinct, but not independent, axes: "Understanding of the Users" and "Design Process and Integration" as shown in Figure 1. The axes depict complex constructs and have scales that were derived from the categories themselves and are ordinal in nature. Five of the categories were nested hierarchically. From less comprehensive to more comprehensive, those categories included: Human-centered design as "User as Information Source Input to Linear Process", "Keep Users' Needs in Mind", "Design in Context", "Commitment" and "Empathic Design". Two categories represented ways of experiencing human-centered design that were distinct: design was not human-centered, but "Technology-Centered" and human-centered design was not design, but "Service". These ways of experiencing design fall outside the two "thresholds" that are described later in the paper.

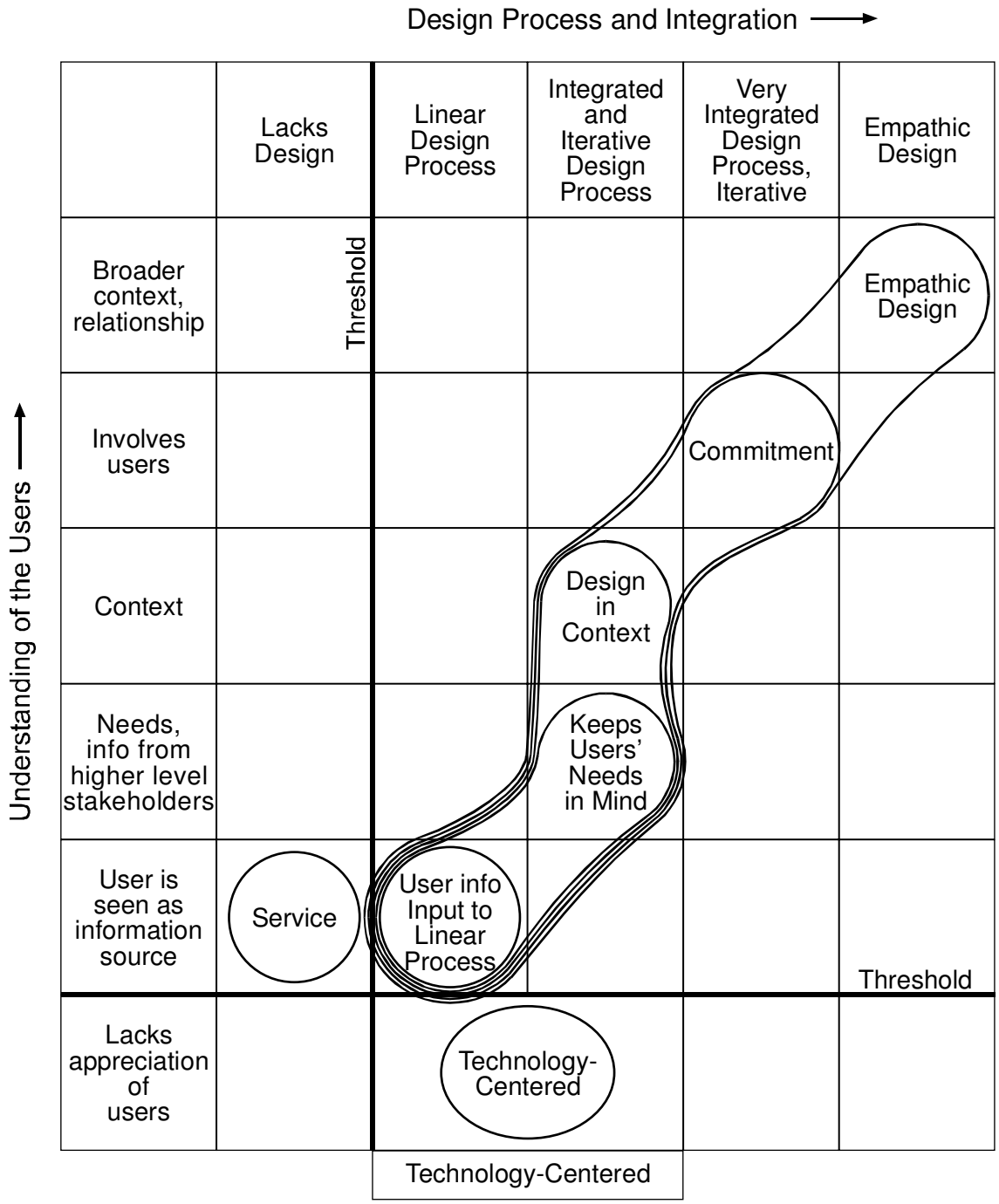

Figure 1: The "Outcome Space" depicting the relationships between the seven ways of experiencing human-centered design that emerged from the interviews[13]

Educational Implications

The findings of the phenomenographic study have many educational implications. The structure of the outcome space itself represents how students experience human-centered design and typical pathways for developing more comprehensive ways of understanding human-centered design. In addition, the students describe different characteristics of their experiences of human-

centered design which can and do impact their understanding. In these discussions, the students often used "user-centered design" to talk about "human-centered design".

Outcome Space

The overall structure of the outcome space (see Figure 1), consisting of the nested hierarchy of categories 3 – 7 and two distinct categories, suggest a number of things. First, that there is both a "design" aspect and an "understanding of the users" aspect reflected in the experiences of human-centered design. Those aspects are consistent with Krippendorff's framework of human-centered design[4] in which there is a design process and understanding of how the stakeholders make meaning of the artifact. Second, the graph of categories 3 – 7 suggests that students' understanding of the user and their ability to integrate that into their design are related in the development of more comprehensive ways of experiencing human-centered design. As the student designers understand users and the context better, they are then confronted with the need to take more factors/aspects into consideration into the design. Therefore, their awareness of the complexity of design increases. Similarly, as design and disciplinary skills increase and are brought to bear on the design, the student designers are more capable of incorporating more complex information about the stakeholders, as well as aspects related to the feasibility and viability, that are not realized without those skills.

Additionally, the findings suggest both design skills and an appreciation of the user are needed in the development of more comprehensive ways of experiencing human-centered design. Although the students whose experiences comprised the "Technology-Centered" group were seniors with design experience, their approach to designing for others was qualitatively different as it reflected a lack of appreciation of the user's knowledge, skills and experiences and the role of the user in design. This implies that becoming human-centered does not result from simply learning more about design or developing disciplinary skills. It also requires some component, whether internally motivated or externally motivated, that moves them in the direction of a better understanding of and increased appreciation for the user. Similarly, the students whose experiences comprised the "Service" group expressed an appreciation for the people that they were "designing" for, but their lack of design skills contributed to a way of experiencing human-centered that was very different from even those student designers with limited design skills.

Finally, within the outcome space, the categories of description themselves depict qualitatively different experiences which help illustrate the progression through the more comprehensive ways of experiences. This both helps to define what it means to have a more comprehensive way of experiencing human-centered design, but what are the typically pathways of development towards that more comprehensive experience. As illustrated in the outcome space, the pathway included development of both.

Threshold Concepts

The framework of threshold concepts[25] also provided insight to aspects of the outcome space. Previously, Kabo and Baillie[26] combined phenomenography and threshold concepts theory to study student's understanding of social justice in relation to their course and engineering practice. Their resulting outcome space consisted of categories of description which fell along the liminal space which characterized the transition from one state of knowing to another. The "spectrum of liminality" included a "pre-liminal" conception that represented no understanding

of the concept of social justice. The "liminal" space consisted of three conceptions of social justice moving from a fragmented view that was at the edge of the threshold to an understanding of social justice that was active and participatory. The "post-liminal" conception of social justice represented an internalized understanding of social justice.

The concept of thresholds was most helpful in consider the two categories that were distinct and not included in the main nested hierarchy of categories: those whose experiences lacked design (Service) and those who did not appreciate the knowledge, experiences and perspectives of the users or the value of involving the users in the design (Technology-centered). For the "Service" group, the design experiences that were described were very task-oriented, and tasks were not seen in the context of the broader design. In addition, the types of information that the students in this group sought were factual in nature, considering basic wants, and/or to get approval. Although they had an appreciation for those they are benefitting or helping, because they were not designing, they did not engage them or involve them in the process. And although designers from the Technology-centered group demonstrated design and disciplinary knowledge, it was technology, not human focused. As such, the student designers did not consider the users as possible contributors to the design, such as involving them to develop the solutions or to understand the broader need, but those for whom a technological solution was being developed. This was demonstrated in three ways. First, it was demonstrated by the lack of involvement of the users in the process, including the limited information that they sought about and from the users and stakeholders. Second, it was demonstrated by whose ideas they listened to when designing, how they viewed communication with their stakeholders, and their frustration when their stakeholders weren't as fascinated by the technology as they were or didn't want a more technological solution because it was "cool". Third, it was demonstrated by how they viewed aspects related to the stakeholders, particularly the users, as add-ons to the design, not an integral part.

There is also a quality of having to overcome a threshold concept to experience human-centered design in a different way for the concepts within the main nested hierarchy. In particular, the transitions from category 5 (Design in Context) to category 6 (Commitment) and category 6 (Commitment) to category 7 (Empathic Design) also demonstrate transformative aspects in students' experiences of human-centered design.

Experience with real clients and users

The results suggest that critical or immersive experiences involving real clients and users were important in allowing the students to experience human-centered design in more comprehensive ways. For example, student designers who experiences comprised the "Commitment" category all described critical experiences that challenged their assumptions about design. Situations which were described included problems associated with delivering a project or prototype to the client. For example, Sejal described her experience in which her prototype was rejected by the patients as a "wake-up call".

> *because initially we had this awesome idea, it was great and stuff like that, and it just wasn't practical and it just wasn't something that anyone would ever use, even if it worked. And so I think that really kind of gave me a wake-up call about what our limits are and like it's not just science, it's not just math; you have to take a lot of other things*

into account. I think throughout the years they gave us all the tools to make something work, but it was this experience and it is further design experience that I will have as an engineer that will help me understand that you have to incorporate all these other factors into my design.

Andrew also discussed how the experiences of having his solutions rejected helped him learn the importance of starting with the humans in mind.

I've had…complete ideas scrapped because they didn't meet the end goal. And so it's kind of like working jointly, and I think from my experiences, in order for it to be successful, an in-depth knowledge of your user has to come first so that you can make sure you're designing to their specifications. But as I've learned and had different solutions rejected, I've realized it is not I'm higher than my user; it is I am on the same page as my user, because my project is not going to work unless it meets what the user needs.

Similarly, all the student designers whose experiences comprised the "Empathic Design" category described immersive experiences with their stakeholders, particularly the users. For example, three of the four student designers whose experiences comprised this category participated in an intensive requirements gathering trip to a remote village where they interacted extensively with a number of stakeholders and brought in information from multiple perspectives into the design. One of the students, Greg, talked about how they met with the doctor, the school teachers, and the "plumber", the person in charge of rationing the water during the dry season.

But we went there, and the doctor gave us very good information. He had a computer and he recorded all the ailments and stuff specific to our village because he sees several villages in the area, and he gave us very specific details about what ailments affect our village.

We want to get a good view of how the village overall was seen, and teachers, I feel like, are a really good resource because they see all the children all the time and they can see any ailments going in the children, you know, whether they have runny noses or whatever…

During the dry season especially, they would have to ration water, and there were certain valves throughout the village that they would turn off and on to ration water to certain sections, and he was, like, the plumber, they called him. Yeah, it was interesting. We had to meet with him. It actually kind of took us a little while to get a hold of him, but he was very helpful by drawing a very specific map of the entire water system that existed already, and the zones and where the pipes are and the valves and everything.

They also met with individual villagers to get their perspective, recognizing that they offered a different view.

Well, after that, we also did—well, individual villagers, we felt like they wouldn't have as much information as a teacher or the doctor could have compiled, so the questions that

we asked individual villagers were more about their specific needs. We interviewed, I think, 8 families throughout the village. They were all on different parts of the water system. We wanted to know how they were using the water, how they were treating the water, where they were getting the water, and basic things like that.

The fourth person in this category, David participated in a rapid prototyping project that involved frequent meetings with the users.

We met with the soldiers at the beginning probably 2 or 3 times a week. The second half of the internship, the last 5 weeks, we were doing a lot more intensive getting the back end to work, so we started meeting with them closer to 1 time a week.

As a result, the student designers whose experiences comprise this category developed a very broad understanding of stakeholders beyond scope of project, interacting with users informally and in social situations. For example, William described that at first he saw the people very objectives, but by spending time with them and learning about them, the people became real.

We realized in the project right when we went down there. Before we did planning, we saw a person as just being something that uses 60 L of water a day; that's a black dot, and there are 180 black dots in this community. Then you go down there and you see that these black dots that are just water users are actually just like amazing people, like real sweet kids, very generous. Everyone is just nice people, and it's just like it's a lot different than just being like some black dot that you just kind of mapped out; it's actually people that you're going to be helping, you're going to be supporting, and it makes it really a lot easier to work hard on.

Similarly, David described the interactions that he had with the users of the hand-held device he was designing for use on the battlefield.

We were showing them mockups, prototypes, and other types of just documentation from our brainstorming sessions, from each of our week's worth of activity. They would just come in, show up, hang out, and get to know us. We got to know them. We went out at a party or would go over to somebody's house or go out to a bar together, so we were really kind of very friendly, very close to each other. But they would come in, and we could say, "Would this work for you?" and they'd be like, "No, no. This would be terrible. It would cause these problems. We wouldn't be able to do this, this, and this that we end up having to do." And so it was very useful for us being able to talk to those users since they had so much experience with what the real world is like out there because all of us interns had no experience with what the battlefield would be like or what to expect from that type of situation.

…having these end users who were our age, who had the experiences but also were somebody we could relate to on a more personal level kind of allowed us to ask the questions we wouldn't normally feel comfortable asking about: "Well, how did you lose your leg? What could we do about the fact that you lost your leg?"

The findings suggest that critical experiences, such as confrontation of ideas when delivering a produce or prototype or immersive and intensive interaction with the stakeholders, are important in allowing the students to experience human-centered design in more comprehensive ways. However, the specific characteristics of these experiences that makes them "critical" (e.g., how immersive do the experiences need to be or in what ways must they confront their ideas?) is not known and requires further study.

Reflection

The interview process itself appeared to be a great learning opportunity for student participants. Many participants commented on how they enjoyed the interview and that they learned from the reflective exercise of the interview. For example, when Heather asked if her views of human-centered design had changed, she replied "Yeah, probably just in this last discussion." Similarly, Julian replied "doing this helped me better understand like human-centered design, like what's involved in that." In addition, Andrew talked about how initially it was difficult for him to define human-centered design, but the interview helped him to do so. He also recommended that it would be helpful for the students in general to reflect on user-centered design in their design courses.

> *I think I kind of said it, but I'd really like to stress that even I think when I went and tried to just define what human-centered design was or user-centered design, like I wasn't able to really do it. I feel like now I have a better understanding of what it is, but it's something I think in learning as engineers, we spend so much time on the principles and the background and going through the engineering process that we don't spend a whole lot of time realizing that, especially in biomedical engineering, what we're designing is directly for patients and for users. And so I think for me it would have been more beneficial if we spent more time describing what user-centered design was and how when we're designing things that's ultimately the end goal, and so a lot of this initial investigation needs to be done; and how a successful project really isn't oh, is it the best purely scientific or engineering design? Is it something that can be used and improve somebody else's life?*

Chloe also commented that she learned as a result of the interview.

> *I feel like I discovered that I did lot more design than I actually thought I did. That was a lot that I didn't even know that could come out. Yeah, but I feel that's how design should be because that's just like why engineers exist.*

The fact that the students learned as result of the interviews is not surprising as the interviews guided them through a reflective experience. This is consistent with the literature on reflection and other metacognitive approaches to learning[12,27-28]. The study suggests that utilizing an interview or reflective activity in which the students explore their experiences designing for others could be an effective educational tool to help students understand what it means to use a human-centered design approach. Simply having an experience working with a real client or user may not be sufficient for the experience to become a "critical experience" without the opportunity for students to process the experience and deepen their learning related to human-centered design.

Human-Centered Design Ideas

Several students described how being introduced to human-centered design concepts brought a new way of thinking about design as illustrated in the following quotes.

> Andres: *I think it was mostly having more things to think about or introducing ideas and ways of thinking about things that you wouldn't always think about normally or wouldn't come up with on your own.*
>
> Gina: *I didn't think in terms of user-centered design when I came to college. You just think an engineer designs things.*

These comments suggest that human-centered design concepts may provide a very different way of thinking about design for some students. Furthermore, as Andrew indicated in his quote above, it may be important that these concepts are explicitly addressed when talking about design because it appears that students do bring a conception of design with them to college, and that human-centered design offers a different perspective on design from what many students currently know.

The Terminology of Human-Centered Design

The study revealed that there were significant misconceptions about the terminology "human-centered design" itself**.** Although the students were able to describe how they "designed for others" in ways that reflected human-centered design, when asked what the phrase "human-centered design" meant, they often repeated a definition that was just a rephrasing of the term.

> Jacob: *So human-centered kind of makes you think of designing it for people.*
>
> Sejal: *Human-centered design is something that immediately affects humans.*
>
> Kylie: *I think it's where it's for the human.*
>
> Salena: *I would assume human-centered design would mean more dealing with a patient because it would be their needs, and if it's a medical device, it would be a patient generally that would need the device.*
>
> Maddie: *A design that affects the end user positively.*

These definitions also often reflected a narrow scope of human-centered design as designing only for things that positively helped people and lacked the depth of the experience of human-centered design which they had described. It suggests that it important not to assume that the students understand what human-centered design means even if they are familiar with the phrase itself. It is also important as an educator exploring the students' experience or understanding of human-centered design, to go beyond the definition.

Context of Experience

The participants for this study were selected to represent the range of experiences in which students might "design for others". In the interviews, most of the students described multiple experiences from different contexts. They often compared and contrasted aspects of the different contexts of their experiences. The students were also asked at the end of the interview explicitly what experiences contributed most to their understanding of human-centered design.

For many of the students, the focus of the design experience was on the academic context. For example, when the students were asked "Reflecting back on your experiences, if you were to change anything related to human-centered design, what it would be?" some of the students described aspects of the course they would change such as how the teaching assistant graded. In addition, students described real or perceived barriers to their design process because of the academic context. Some students described the design being guided significantly by the course assignments and grading. Other students reported difficulties engaging the users which impacted their experience of human-centered design. For example, Megan described how her interaction with her customer was not ideal:

> *if I were designing for someone, I would want to keep in contact with them a lot more often. She is kind of hard to get a hold of and it's not—we're kind of on the back burner, it seems like.*

This is consistent with Scott's findings that the students often underestimated the complexity and difficulty of engaging users when beginning the project, and when faced with the challenges in the midst of the project, sometimes responded by "retreating from deeper forms of user engagement. Thus, the tension between students' user-friendly and user-centered notions of usability was related to a disjuncture between their expressed valuing of user-centered design and their mixed attempts to enact it."[29]

Another area of context that emerged from the study is how the students perceived various experiences and the impact of their perceptions on their learning. For example, the students talked about the "realness" of the context as it related to their experiences, both in regards to the person they were designing for and whether or not the experience was academic or work related. They described approaching the design differently because the context did not require them to meet requirements such as safety or durability because the project would be disposed of at the end of the semester. Whether or not that different behavior is desired is most certainly an open question within the design education community. However, most design educators would agree that it is important to understand how the context affects the student's learning of design and more work is needed in this area.

Limitations

The results of this study regarding how students experienced human-centered design must be considered within the context of the study. Although the students described a wide variety of experiences, most of the experiences were within the academic context and were subject to the real and perceived barriers as described in the previous section. Therefore, it is not expected that the results would necessarily be generalizable to the experiences of students working exclusively in a professional context or to a context where the designers were professional designers.

Although experts in human-centered design were not included as part of the sample, the literature and research studies related to human-centered design in practice and design expertise informed the study. In addition, experts in human-centered design were consulted as validity and reliability checks of the results. While this study focused on student designers in order to contribute towards our understanding of the experience and learning progressions of students, a future study could be conducted to investigate the variation in practitioners' experiences with human-centered design.

Future Work

This study investigated the qualitatively different ways which students experienced human-centered design. The findings of this research are important in developing effective design learning experiences and have potential impact across design education. This study provides the basis for being able to assess learning of human-centered design which will allow educational programs to determine their impact, and what aspects are most effective. The findings from this study also generated several questions for future study:

- What are the specific characteristics of the "critical experiences"?
- Are certain types of educational programs and experiences more effective in developing students' understanding of human-centered design?
- Are the experiences sufficient, or is it necessary for the students to have an opportunity to "unpack" the experience and connect to other aspects to make them effective learning experiences? If so, what are effective ways to integrate reflective activities into the design learning experience?
- What are the relationships and the impact of the academic context on students' design experience and learning?
- What are the qualitatively different ways that experts and practitioners experience human-centered design? How does that compare to the students' understanding?
- Can the categories of description be used as a basis for developing an instrument to assess students' ways of experiencing and understanding human-centered design? The findings of this research have potential impact across design education.

Understanding the development of human-centered understanding in design learning could greatly enhance the way engineers learn design and the other attributes being called for by ABET, the NAE's Engineer of 2020 and industry in today's global economy. Understanding the ways in which students experience human-centered design are important to develop effective design learning experiences to help cultivate student's understanding of how to design for others.

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