Students’ Ways of Experiencing Human-Centered Design

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BACKGROUND
Design is a central and distinguishing activity of engineering and one of the core criteria for evaluating and accrediting engineering programs. Design is also a subject area that poses many challenges for faculty, and incorporating human-centered design approaches—approaches in which designers have as a focus the people they are designing for—poses additional challenges. Human-centered approaches to design contribute to innovations in engineering design and have been shown to increase productivity, improve quality, reduce errors, improve acceptance of new products, and reduce development costs. In today’s globally competitive economy, it is more important than ever to develop effective design skills within the undergraduate years.

PURPOSE (HYPOTHESIS)
Before effective design learning experiences to develop the skills needed for human-centered design can be created, an understanding of the ways in which students understand and experience human-centered design is needed. This study addresses this need by investigating the qualitatively different ways in which students experience human-centered design.

DESIGN/METHOD
A phenomenographic framework was used to guide the methodology of the study while the literature and research on human-centered design informed the construction of the study and provided ways to interpret the data and situate the findings. Thirty-three student designers from a variety of academic contexts were interviewed using a semi-structured, open-ended approach in which they discussed concrete experiences “designing for others,” and reflections and meanings associated with those experiences.

RESULTS
Analysis of the data yielded seven qualitatively different ways in which the students experienced human-centered design; these seven categories of description formed a two-dimensional outcome space. 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.”

CONCLUSION
This study found that i) students’ understanding of the user and ii) their ability to integrate that into their designs are related in the development of more comprehensive ways of experiencing human-centered design, and a conception of both aspects is needed. Furthermore, critical or immersive experiences involving real clients and users were important in allowing the students to experience human-centered design in more comprehensive ways.

KEYWORDS
human-centered design, phenomenography, user-centered design
INTRODUCTION

Design has been defined as a “systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients’ objectives or users’ needs while satisfying a specified set of constraints” (Dym, Agogino, Eris, Fey and Leifer, 2005). It is a central and distinguishing activity of engineering (Simon, 1996) and a core criterion for evaluating and accrediting engineering programs (ABET, 2000). Recently it has been argued that there is a paradigm shift occurring in design from “technology-centered design” to “human-centered design” (Krippendorff, 2006). Technology-centered design has been defined as a process in which the designers or their clients make design decisions which are imposed on the intended users (Krippendorff, 2006; Hoffman et al., 2002). In contrast, IDEO (2011) defines human-centered design as:

A process and a set of techniques used to create new solutions for the world. Solutions include products, services, environments, organizations, and modes of interaction. The reason this process is called “human-centered” is because it starts with the people we are designing for. (IDEO, 2011, p. 6)

This definition of human-centered design is consistent with Zhang and Dong’s (2008, p. 3) review of several “human-centered” design approaches that found that all of the approaches have human beings as central in the process, involve users throughout the design process, and seek to understand them holistically. In addition, the processes included multi-disciplinary collaboration in order to make products and services useful, usable, and desirable. Similarly, Krippendorff (2006, p. 230) identifies three features shared by different human-centered design methods: (1) they are “design methods” that employ both divergent and convergent thinking; (2) the processes are concerned with how the stakeholders themselves attribute meaning through the use of the proposed design; and (3) the methods include prototypes and other ways for the stakeholders to test the design ideas themselves since “a projected future cannot yet be observed.” Note that all definitions describe human-centered design as distinct from simply the design of something that is user-friendly; instead, human-centered design involves and values stakeholders throughout the design process rather than checking for “user-friendliness” at the end of the process.

The shift to human-centered design processes may be occurring as leading design firms such as IDEO are attributing their success in innovation to human-centered design processes. In addition, according to Tim Brown (2008), CEO and president of IDEO, in order for engineering graduates to make an impact in the global workforce, they must develop “design thinking,” which he defines as “a discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity” (p. 86). It is not surprising that researchers and engineering educators at Stanford University also embrace a human-centered design process (Stanford Institute of Design, 2010), as IDEO’s founder David Kelley is a professor of mechanical engineering at Stanford and the head of the new Hasso-Plattner Institute of Design at Stanford University.

Engineering education has increasingly incorporated and taught human-centered design processes and focused on the development of skills needed for design thinking (Agogino, 2008; Buchanan, 2001). Furthermore, this shift is expressed by Shulman (2008, p. x), who states that “the process of engineering design increasingly places the human impact of design and its products at the center of the deliberations.” How might it have been
designed otherwise?” is a question about the human consequences of human invention, a consideration of engineering design as a social and humanistic field as well as a technical and scientific one.

A critical part of design thinking and human-centered design is understanding the people affected by the design. There are many examples cited in the literature that point to the lack of understanding of the user, or an understanding of the way in which the product would be used, that contributed to its failure (Casey, 1993; Damadaran, 1996; Norman, 1988). However, 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 (Damodaran, 1996; Maguire, 2001).

**Purpose of the Study**

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? Before we can answer these questions, we first need to understand the variations in the way that students experience and understand human-centered design, understand the role of the users and other stakeholders in design, and incorporate the various stakeholders’ needs into the product. Understanding these variations is important in structuring appropriate and effective educational experiences, instructional materials, and assessment instruments.

There are two specific aspects that are of particular interest. First, how do students currently experience and understand human-centered design? Secondly, how are those variations of experiences related to each other and which represent more comprehensive ways of experiencing and understanding human-centered design? The first aspect is important because awareness of the variations of the students’ experiences, and specifically their conceptions and misconceptions, allows educators to build upon the student’s conceptions and target misconceptions (Bransford, Brown, & Cocking, 2000). 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.

**Research Question**

The research question which guided this 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”?

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 National Academy of Engineering’s Engineer of 2020 (National Academy of Engineering (NAE), 2004; NAE, 2005), and industry in today’s global economy. Understanding the ways in which students experience human-centered design is important to effectively design learning experiences to help develop that skill. Furthermore, the study provides the basis for being able to assess learning of human-centered design. The ability to
assess students’ understanding of human-centered design will allow educational programs to determine what impact their programs are having, and what aspects of the educational program are most effective. The findings from this study will also provide the underlying framework of students’ experiences of human-centered design so that future research studies can examine which kinds of experiences contribute most to the students’ learning of human-centered design.

**Theoretical Frameworks**

The design of this study was shaped by a variety of frameworks. Because the goal of the study is 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 as a research framework is discussed in more detail later in the paper). In addition, the literature and research on human-centered design informed the construction of the phenomenographic study and also provided ways to interpret the data and situate the results.

**Human-Centered Design Processes**

Design has been characterized by many different “design process” models (Atman et al. 2007; Bennett, 2006; EPICS, 2009; Mosborg et al., 2005; Ullman, 2003) which reflect different design approaches and philosophies. Among these models are those which are explicitly referred to as human-centered, along with several models which are “human-centered” but are not strictly labeled as such. Consideration of these different models helps to both illuminate what it means to be human-centered, but also the variation that exists among human-centered design approaches. For example, although user-centered and human-centered design approaches are similar, user-centered design focuses on the end-user of the product, whereas human-centered design considers the stakeholders more broadly than the stereotypical user (Krippendorff, 2006). Although the human-centered design processes and methodologies which have emerged in recent years share a focus on the users and other humans in the design process, they differ in their motivations and how the user/humans are involved. Damodaran (1996) describes a continuum of the user involvement in human-centered design from informative, through consultative, to participative.

Another human-centered design approach, empathic design, has been described by IDEO (2011) as follows:

> Empathic design is not a method in which preconceived ideas and assumptions are substituted for grounded research and connection with end users. Although solutions are generated by the design team, the goal is to always have the people you are designing for in mind. (p. 89)

The participatory design approach grew from work that began in the early 1970s in Norway (Sanoff, 2007) and is defined by Kensing and Blomberg (1998) as “a commitment to worker participation in design and an effort to rebalance the power relations between users and technical experts and between workers and managers.” Contextual design (Beyer & Holtzblatt, 1998) is another human-centered approach to design where the focus is understanding how the customer works, or the context in which the product is used. It involves exploring the customers and their environments through ethnographic inquiry, and then building work models to capture that information. The individual perspectives are consolidated to reveal common patterns and structure and to complete a redesign of the work practice.
Keates and Clarkson (Keates & Clarkson, 2003; Clarkson, Coleman, Keates, & Lebon, 2003) describe inclusive design as a derivative of user-centered design. It is a design philosophy and methodology whose goal is to allow the greatest number of people to use the product being designed. A basic premise of inclusive design is that design should not exclude users any more than essential task requires.

Many of these human-centered design processes (as well as others) are synthesized in Sanders’ (2008) mapping of design practice and design research approaches. Sanders’ map consists of two dimensions: approach and the mind-set. The approach dimension was defined by whether the approach was design-led or research led. On one side of the mind-set dimension, designers see themselves as experts. On the other side, designers have a participatory mindset. This map provides an overview of the space of different human-centered design processes.

Human-Centered Design Research and Literature

There are a number of research studies and a wealth of design literature that describe dimensions of human-centered design. These dimensions provided a framework for exploring students’ experiences and understanding of human-centered design within the study. For example, one dimension is the variation in the temporal aspects of user-related activities during the design process. Users and stakeholders are engaged in significant ways in human-centered design processes that is not reflected in many general design processes. The nature of the involvement is reflected in both the activities themselves as well as the temporal aspects. Thus, the temporal aspects of the design process, as well as other dimensions provided a framework for exploring students’ experiences and understanding of human-centered design within the study. Other dimensions that were considered are described in the following sections.

Gathering Information About the User

Designers gather information from and about their users through a variety of methods. Dym and Little (2004) identify several techniques for acquiring design information: literature review, user surveys and questionnaires, focus groups, interviews (formal and informal), brainstorming, synectic activities to develop analogies, benchmarking competitive products, and reverse engineering or dissection. Additional techniques for acquiring design information include observation, ethnography, role-playing, semantic differentials (Lawson, 2004), and paired comparisons (Jacobs & Ip, 2005). In addition, scenarios have been used to describe the context of a user’s experience with products (Jonas, 2001; Kurakawa, 2004; Shambaugh, 2004).

Another method that designers have used to gather and use user information is through the development and use of personas (Guenther, 2006)—fictional stakeholders. Personas are different from use cases and are intended to provide broader insight, and connect the design team to a tangible user to provide the “big picture” and connect design activities. They can be used throughout the design process to help assess the development of the product to still make sure it is meeting the needs of the users and to remind the designer to design for the user, not for the designer’s own wants, needs, and interests.

Finally, empathic modeling is used often in inclusive design to develop a better understanding of how a user might experience a situation or product. This is a “method whereby an individual, using various props and scenarios, is able to simulate the deterioration of physical and perceptual abilities in everyday scenarios, for example, by using spectacles to feign the effects of reduced visual acuity” (Nicolle & Maguire, 2003).
How Do Students Apply the Information About the User?

Although there is a great deal of discussion and research regarding general design processes, including decision-making in design, there has not been a great deal of research completed about how the designers, and in particular, the students, consider the users’ issues in making decisions. However, Sugar (2001) looked at the effect of usability sessions on novice software design and found that, although the students thought the usability sessions were helpful, they had minimal effect on their designs. When they did make a change, they were one of two simplistic solutions that demonstrated only a surface-level understanding of the problem. The first type of solution to a problem uncovered in a usability session was the delete solution. If something was a problem, they simply deleted it. The second type of solution was the Band-Aid solution. For example, one of the teams determined that “their ‘users did not know where to click, or what the icons meant.’ So, they decided to have written directions to assist their users” (Sugar, 2001). Therefore, instead of understanding the comments to mean that the site was not very usable, they attempted to address the problem through the written directions. The findings from this study provide a framework to consider how students incorporate users’ issues in their design.

User Engagement

In a study of teaching user engagement through service-learning, Scott (2008) found 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.” Furthermore, as the project continued, most students found ways to simplify their user-engagement efforts. This study highlights issues of user engagement which may impact the students’ experience of human-centered design.

Design Expertise

Variations in design experiences can also result from differences in design expertise. A number of studies describe the behaviors of expert versus novice designers, and specifically the characteristics of outstanding designers. Christiaans and Dorst (1992) found that novice designers tend to spend a disproportionate amount of time in the information gathering phase of design without progressing towards quality design solutions. Atman, Chimka, Bursic, and Nachtmann (1999) also found that some novice designers in their study spent extensive periods of time gathering information without progressing towards developing detailed solutions while most novice designers engaged in virtually no information gathering. Newstetter and McCracken (2001) found that (1) students perceived design as coming up with good ideas, but not the realization and evaluation of those ideas; (2) novice student designers often design for themselves and do not situate the design in context; and (3) that students often focus on a single solution beyond the brainstorming phase and perceive of design as a linear process. In another study comparing expert engineers to engineering students, Atman et al. (2007) found that the most significant differences between experts and students were in their problem scoping and information gathering skills. In addition to gathering more information in general, they found that the experts gathered more information that related to the users and the situation context than the students. From a meta-analysis of design studies, Cross (2004) concluded that successful design behavior depends on adequate problem scoping and an active approach to problem framing.
which is solution-focused. It is also associated with frequent switches among types of cognitive behavior. However, Cross found that not all expert designers employ strategies which are recommended or taught as the “right” way to design. For example expert designers do not typically generate multiple solution concepts, and rely on intuition although their design solutions are considered of higher quality. These differences reported by Christiaans and Dorst (1992), Atman and her colleagues (1999; 2007), Newstetter and McCracken (2001) and Cross (2004) in problem framing, problem scoping, information gathering behavior, realization and evaluation of design solutions and concept generation all represent potential variation in design expertise that we might see in student designers’ experiences.

**RESEARCH APPROACH**

To build on the previous studies of design processes, human-centered design, and expert-novice differences, the goal of this study was to characterize the qualitatively different ways in which the students experienced human-centered design. The methodology selected for this study was phenomenography, a qualitative approach to research in which the “unit of phenomenographic research is a way of experiencing something, …, and the object of the research is the variation in ways of experiencing phenomena” (Marton & Booth, 1997). 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 (Marton, 1981, 1988). Therefore, 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 well-suited for the study.

Phenomenography has been used to study very similar types of questions. It has been used to research and identify different ways of experiencing a wide variety of phenomenon from students' experience of learning object-oriented programming (Stamouli & Huggard, 2007) to the quality of care in the psychiatric setting (Schroder, A., Ahlstrom, G., & Larsson, 2006). Related to design, phenomenography has been used to explore sustainable design (Mann, Radcliffe, & Dall’Alba, 2007), design students' experiences of engagement and creativity (Reid & Solomonides, 2007), and the ways that design has been experienced by professionals in a variety of disciplines (Daly, 2008). It is important to note that phenomenography is different from phenomenology. Although both qualitative methods are concerned with how a phenomenon is experienced, phenomenology investigates the essence of a phenomenon whereas phenomenography seeks to understand the variation (Patton, 1990).

**Outcomes of Phenomenography**

The outcomes of phenomenographic study are the categories of description and outcome space. Marton and Booth (1997) 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 (Åkerlind, 2005). Furthermore, since phenomenography looks at the variation within the sample group as a group, the outcome space provides a way to look at the collective experience of the phenomenon versus the individual experience. Marton and Booth (1997,
p. 125) identify the following three criteria for determining the quality of the categories of description and the outcome space:

1. “Each category tells us something distinct about a particular way of experiencing the phenomenon.”
2. “The categories have to stand in a logical relationship with one another, a relationship that is frequently hierarchical.”
3. “The system should be parsimonious, which is to say that as few categories should be explicated as is feasible and reasonable, for capturing the critical variation in the data.”

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.” The service-learning pedagogy is of particular interest because of the learning benefits in general, and specifically the access to real users. However, because 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 the EPICS courses (Coyle, Jamieson, & Oakes, 2005), Engineers Without Borders (EWB) or Engineers for World Health (EWH). It also included more traditional design courses, internships, and other experiences such as the Mechanical Engineering, Biomedical Engineering and Electrical and Computer Engineering senior design courses, and the first-year “User-centered Design” courses in Engineering Education. Using maximum variation sampling (Creswell, 2003; Patton, 1990), 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. IRB approval was obtained prior to the commencement of the interviews.

A summary of the participants is given in Table 1. Many of the students participated in multiple experiences in which they “designed for others.” Some of those experiences were situated in curricular contexts that included projects in service-learning, senior design, and other courses. Other experiences involved co-curricular projects such as EWB and EWH, as well as undergraduate research, internships, and other work experiences. The students also described community service projects, projects completed while in high school, scouting projects, the design of athletic practices and the design of Rube Goldberg projects. The number of semesters that the students participated in the course or activity ranged from one to five semesters.

**Data Collection and Analysis**

The data collected for this study was interview data. 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. Because only the evidence from the interview transcripts is used to develop categories, the design of the interview protocol is critical. Each interview began with an identical opening scenario and included follow-up questions to elicit more discussion about the phenomenon. The protocol was piloted before formal study began to critique both the protocol and the interview technique. The final interview protocol is given in Appendix A.

The interviews were transcribed verbatim and the transcripts and notes associated with each interview were coded with a pseudonym. The phenomenographic analysis process was strongly iterative and comparative and began by reading and re-reading the entire set of interviews (Åkerlind, 2005; Bowden and Green, 2005; Marton and Booth, 1997).
<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Year</th>
<th>Major</th>
<th>Sex</th>
<th>Ethnicity (Free Response)</th>
<th>Types of Experiences “Designing for Others”</th>
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</thead>
<tbody>
<tr>
<td>Clare</td>
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<td>Caucasian</td>
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<td>M</td>
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Considering each transcript holistically and within the context of all of the interviews, the transcripts were sorted into initial categories. Similarities and differences among the groups were described, which served to help clarify and refine the categories. Categories were formed based on the content of the transcripts themselves, rather than base on theoretical framing from the literature. Several iterations of this process were completed. When the categories began to converge, analysis of the structural relationship between the

<table>
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<td>M</td>
<td>Indian</td>
<td>Project in service-learning course, Senior design project, Class project</td>
</tr>
<tr>
<td>Andres</td>
<td>Senior</td>
<td>ECE</td>
<td>M</td>
<td>Caucasian</td>
<td>Senior design project, Internship</td>
</tr>
<tr>
<td>Emily</td>
<td>Senior</td>
<td>ME</td>
<td>F</td>
<td>Caucasian</td>
<td>Internships, Design class project, Senior design project</td>
</tr>
<tr>
<td>Joe</td>
<td>Senior</td>
<td>ME</td>
<td>M</td>
<td>Caucasian</td>
<td>Project in service-learning course, Internship, Senior design project</td>
</tr>
<tr>
<td>Amelie</td>
<td>Grad</td>
<td>Audiology</td>
<td>F</td>
<td>Caucasian</td>
<td>Brochure, Project in service-learning course, Educational programs in residence hall</td>
</tr>
</tbody>
</table>
categories began and continued until a quality outcome space (described earlier) had been achieved.

**Validity and Reliability**

Communicative and pragmatic are two types of validity checks common with phenomenographic studies (Åkerlind, 2005). The communicative validity check requires the researcher to be able to defend the results to the research community, as well as representatives of the research sample (although not the interviewees themselves). These are typically achieved by establishing a dialogue with the interviewees, focusing on the transcripts as a whole, by working with other researchers during the analysis and by defending the results to other researchers at conferences, seminars, and in peer-reviewed journals. The first part was accomplished by informing the participants that they would be asked to share their experiences related to human-centered design and there were no right or wrong answers. In addition, the semi-structured format of the protocol encouraged a dialogue between the interviewer and participant. The second part was accomplished during the analysis as described in the previous section. The third part was accomplished by presenting and discussing preliminary findings with several members of the research group throughout the analysis process. In addition, the validity of the results was further established by presenting the findings to experts who teach human-centered design and receiving feedback that the results resonated with their knowledge and experience. The pragmatic validity check tests the extent to which the results are seen as useful to the intended audience. This was achieved by presenting results to engineering educators and researchers and receiving feedback as to how the results could be applied in their own work. In addition, this work is providing a guiding framework for additional research and curriculum development.

According to Åkerlind (2005), “reliability may be seen as reflecting the use of appropriate methodological procedures for ensuring quality and consistency in data interpretations (Guba, 1981; Kvale, 1996).” However, two forms of reliability checks that are commonly used in qualitative data analysis, coder reliability, and dialogic reliability, are not uniformly used in phenomenography. Instead, reliability is ensured by detailing the interpretive steps of the study and presenting examples to illustrate those steps. These details are presented in this paper throughout the methodology, results, and discussion sections.

**RESULTS**

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. An overview of the categories of description is given in Table 2. Table 3 summarizes the main differences between the categories. Rich descriptions of each category with illustrative quotes from the interviews follow the outcome space.

The seven categories of descriptions resulting from the study formed an outcome space with two 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. The placement of the scales along the axes was consistent with the literature and research on human-centered design. For example, increased involvement of the user along the vertical axis was consistent with the characteristics of the human-centered design approaches. In addition, the scales along the horizontal design axis reflected progression of design skills and strategies from novice to more expert-like.

Five of the seven categories, namely categories 3 through 7, were related such that, starting with category 3, each subsequent category represented a more comprehensive way of experiencing human-centered design. Although logically related, the experiences of two of the categories (categories 1 and 2) were not included in that group. The critical differences between the categories provided the basis for developing the hierarchy as represented in the outcome space. Therefore, categories that are more comprehensive will have aspects that are only found in that category as well as aspects that are found in the categories that are less comprehensive.

### TABLE 2
**Categories of Description of Students’ Experience of Human-Centered Design**

<table>
<thead>
<tr>
<th>Category of Description (Human-Centered Design is...)</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1: Technology-Centered</td>
<td>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)</td>
</tr>
<tr>
<td>Category 2: Service</td>
<td>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)</td>
</tr>
<tr>
<td>Category 3: User as Information Source Input to Linear Process</td>
<td>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)</td>
</tr>
<tr>
<td>Category 4: Keeping the Users’ Needs in Mind</td>
<td>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)</td>
</tr>
<tr>
<td>Category 5: Understanding the Design in Context</td>
<td>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)</td>
</tr>
<tr>
<td>Category 6: Commitment to Involving Stakeholders to Understand Perspectives</td>
<td>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)</td>
</tr>
<tr>
<td>Category 7: Empathic Design</td>
<td>Human-centered design is Empathic Design, basing design on knowledge 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)</td>
</tr>
</tbody>
</table>
In their experiences designing for "others," the student designers whose experiences comprised this category demonstrated a lack of appreciation of the users' experiences, knowledge, and perspectives and how this information can inform the design. Although these designers 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, so they did not consider involving the users in developing solutions or in understanding the broader need. Instead they saw the users as people 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 were not as fascinated by the technology as they were or did not 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. This way of experiencing human-centered design as technology-centered is illustrated by Emily's definition of user-centered design:

…user-centered design, where there are certain requirements that have to be met, but they aren't necessarily engineering requirements, like it should be blue or it should be stretchy, things like that where it's not really integral to the engineering of the product, but it's something that the end user wants. And then also kind of common sense things like having an on/off switch or having somewhere to store it, because those are not necessarily things that you would need from an engineering and test standpoint.

A technology-centered approach to human-centered design represented a critical qualitative difference between category 1 and the rest of the categories. Within the outcome space, this category represented a threshold concept, which according to Meyer and Land
Although the designers in this category demonstrated design and disciplinary skills similar to designers in other categories, their focus on technology and not the people represented a way of thinking that limited the way in which they understood human-centered design which was distinct from the other categories.

**Category 2: Service**

The students whose experiences comprise this category were not engaged in design as characterized by design methods and processes. Instead, they had a goal and accomplished tasks related to that goal. Therefore, “designing for others” became “for others,” or service. This was reflected primarily in three ways. First, the design experiences that were described

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**Figure 1. Outcome space for students’ ways of experiencing human-centered design.**

(2003), is “akin to a portal, opening up a new and previously inaccessible way of thinking about something.” Although the designers in this category demonstrated design and disciplinary skills similar to designers in other categories, their focus on technology and not the people represented a way of thinking that limited the way in which they understood human-centered design which was distinct from the other categories.
were very task-oriented, and tasks were not seen in the context of the broader design. Second, 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 benfitting or helping, because they were not designing, they did not engage them or involve them in the process. For example, James had been a Boy Scout and talked about his Eagle Scout project which was to collect as many household necessities and medicine items as possible for the community center. His approach was to combine as many different ways of collecting items as feasible. While some of the activities he used could be classified as design activities, he did not describe them in a way that incorporated many aspects of typical design processes and design language.

So what I did was I went and took different ideas that had been done before and then put them all together. The first one was to set bags in the back of two or three different parishes…the second one was to have a dress-down day. For my high school, we had a dress code, so we had dress-down day…then the third … we put a barrel outside, and then I organized different scouts in my troop to stand outside the barrel, hand out the flyer, and explain what was going on.

The third way that this way of experiencing human-centered design reflected the service aspect was how all of the students defined human-centered design as design that benfits or helps someone. An example of this is Alisa’s definition of human-centered design:

…producing something, whether it is an event or an actual product that fulfills a need for someone—helps them with a problem they’re having, helps them through something, educates them, that kind of thing—more so than just designing a product for entertainment or that kind of thing.

The experiences of category 2 comprised a distinct category that was self-inclusive, similar to category 1. Also within the outcome space, category 2 represented a threshold concept along the “Design” axis. Although the designers in this category demonstrated some appreciation for the people that they were “designing” for, their lack of design methods and processes limited the way in which they experienced human-centered design which was distinct from the other categories. The lack of design methods and processes is a critical qualitative difference between category 2 and the rest of the categories.

### Category 3: User as Information Input to Linear Process

The experiences of the student designers in this category reflect the dependent nature of the students’ understanding of design and their understanding of the user. In contrast to the first two categories, this category describes experiences that form the basis of human-centered design. Human-centered design processes by definition consist of design methods and processes and an appreciation for the knowledge, information, and experiences of the user, and category 3 reflects both of those aspects, although in limited ways. The student designers of category 3 considered the user as an information source which they incorporated at the beginning of the design process. Their design processes were linear in nature, but still demonstrated aspects of convergent and divergent thinking and utilized design methods. Although the student designers described including the stakeholders in the design, they did not involve them to better understand and meet their needs, but instead so the stakeholders could help them with the design.
This way of experiencing human-centered design is illustrated by Kylie's comparison of the design processes she used in her internship experience and in her design course; she described them both as problems where all of the "givens" were determined at the beginning of the process and did not involve iteration or feedback from the user.

So I think with any problem, you start out with the same thing: I'm asking this, I'm asking that, I'm setting my problem up, I'm getting my given, I'm figuring out what I need to find, and then I'm setting up my solution. And I think that's generally the same thing that you would do for any design problem or problem, period.

They gathered information about the stakeholders, but if the design got too messy, they would disregard the information or choose a path that did not require them to incorporate that information. For example, when Daniel realized that he could not generate enough energy for the target group, he changed the target group.

We had it planned to be people who are away from power devices or power grids, and that was kind of too vague because almost everyone is away from like a power grid at one point in time. We changed it to people who are walking, but then we figured that walking really doesn't produce that much mechanical energy, so we needed somebody who was actively doing something, and then that's how we got to that.

In summary, this category reflected both an understanding of the user and design processes skills, although limited, which formed the basis of more comprehensive ways of experiencing human-centered design.

**Category 4: Keeping Users' Needs in Mind**

The student designers in this category describe human-centered design as keeping in mind the users' needs and how design will be used. A critical variation between category 3 (User as Information Input to Linear Process) and category 4 (Keeping the Users' Needs in Mind) was the emphasis on understanding the need and integrating that information with other aspects of design. Category 4 moved beyond considering just the wants and sought to understand the users' needs and how artifacts can be used. This information (related to needs and use) was integrated with other aspects of the design, not just at the beginning as with the category 3 designers, but throughout the design. As a result, the design process used by the student designers in category 4 was more iterative. The consideration of broader information such as needs versus wants demonstrated a more comprehensive way of understanding the nature of the "problem" to be solved in design. In addition, iteration demonstrated by the student designers in category 4 was characteristic of more informed design processes, and thus more comprehensive than the linear process demonstrated by the student designers of category 3.

This is illustrated by Ben's description of how the users' needs were considered throughout the design process:

…it's completely connected to the users. So from market analysis, you have to understand what your users want and what they need and what the prevalence is of whatever you're trying to treat or diagnose or fix. And then as you're designing, you should be getting feedback from them so that you can make sure you're on the right track and you're meeting their needs.
The type of information that the student designers sought and from whom they sought it also reflected their understanding of human-centered design as “keeping the users’ needs in mind.” The student designers in this category sought more than basic information about the stakeholders, considering their needs as well as how the artifact will be used. They also sought information primarily from higher level stakeholders instead of the users themselves. For example, for her design of an exhibit for a local children’s museum, Gina obtained information about the children’s needs and how it would be used from the client, the director of the museum:

…they gave us a better feel for things like the height of the children, so if they wanted to use something, how could we make that so it was at their level so they could see it or so they could interact with it? Also, the energy level and the attention span. We couldn’t make something that would be very breakable because if they were running around, they could hit it and break it. Or with their attention span, you couldn’t make a video too long because they’re going to lose interest and run away.

Nishant described balancing functionality, when needed, and budgetary constraints in the design of the educational project for the middle school which illustrates how aspects of technical feasibility and viability were integrated with the needs of stakeholders:

…we just realized, because we had promised the teachers that we would be delivering by the end of the semester, going into details like that…would just make the project more heavier, bulkier, more expensive, much more expensive than what we intended it to do, and would just drag it on until probably next semester.

Seeking to understand the need versus just the wants or information provided from the users was a key aspect in understanding the critical qualitative differences between categories 3 and 4. In addition, the efforts to understand the need required a more iterative design approach that was more comprehensive.

Category 5: Understanding the Design in Context

The student designers in this category demonstrated an understanding of the design in context, seeking and considering not only the needs of the stakeholders and how the design will be used, but also broader contextual issues related to the design. This emphasis on understanding the context of design is a critical variation between category 4 (Keeping the Users’ Needs in Mind) and this category (Understanding the Design in Context). In addition, designers whose experiences comprised category 5 tried to take the users’ perspective when designing. Instead of beginning with their own assumptions, they try take the perspective of the people they are designing for. The consideration of the context in which the needs and use are situated and taking the perspective of the user demonstrated a more comprehensive way of experiencing human-centered design. In addition, resulting design process is more integrated and more comprehensive.

The broader understanding was reflected in the experiences of the student designers in a variety of ways: the discussion of the need to understand the specific context of the design; in the explanation of “why” a requirement was needed versus just discussing the requirement itself; or in their understanding and consideration of the hopes, dreams and fears of the people they were designing for. For example, Chloe was part of a team that was
designing a medical device for a developing country. Her understanding of the broader context is illustrated by her recognition that the experiences of a doctor in an established hospital are different from those of a doctor in a developing country.

Like if you are designing an x-ray machine that a doctor in a developing country hospital is going to use, you're not going to want to ask the doctor at [Major US Hospital] if it can work for him because he has all these capabilities, he's probably been trained to use a lot of different machines that the other doctors haven't been trained to use, he has all this lab space, he has this like pristine laboratory.

Similarly, in his design of the soap box derby car for children with special needs, Michael considered the needs of various stakeholders, but from their perspective.

We did a lot of trying to put ourselves in other people's shoes. That was another reason we went down to [City], just to see how different people handle being in the cars and like the different scenarios we would have to face. So a lot of it was thinking about things in a different way than what we normally were thinking.

This also is illustrated by Amelie, an audiology student who had worked with patients directly. Her broad understanding of the user was reflected not only by her discussion of her patients' struggles when they were working with the devices, but also by her consideration of their fears and concerns.

I was thinking when I'm working with them and seeing them struggle, “What would make things easier for them?” For example, I insisted we put a mirror in it because sometimes it's really hard for people to even put it in their ear....And some people don't like doing it in their bathroom because they're paranoid about dropping it in the toilet or the sink; so if it was like a mirror case, to put it in there.

Seeking to understand the context versus just the needs and taking the perspective of the user were key aspects in understanding the critical qualitative differences between categories 4 and 5 which represented a more comprehensive experience of human-centered design.

Category 6: Commitment to Involving Stakeholders to Understand Perspectives

A critical variation between category 5 (Understanding the Design in Context) and category 6 (Commitment to Involving Stakeholders to Understand Perspectives) was a commitment on how it “needs to be” based on knowledge versus how it “should be” based on belief. Students in this category described experiences that challenged the assumptions they had made in the design process and gave them not only an understanding, but a commitment to the belief that it is very important to involve the stakeholders in the process. They realized that design is much more complex than they originally thought. At first they thought the hard part of the design was to solve the medical or technical need, but they realized that it is much more of a challenge to do so in a way that also meets the needs of their patients, users, and/or stakeholders. This commitment is illustrated by Sejal who was designing an intraocular pressure sensor for at-risk glaucoma patients for her senior design project. Originally she thought the design was “awesome,” but it was invasive and the patients were not willing to use it. This experience challenged how she thought about design and made her realize the need to involve the patients in the design to understand their perspectives on the design:
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.

A second critical variation emphasized seeking to understand the multiple perspectives of the stakeholders and balance them with the technical aspects of the design. Although she did not include the teacher in the design of the therapeutic toy for kids with special needs, Ava realized that she should have, and that she needed to take into consideration the needs of multiple users.

If I can go back in time, I would get [Teacher] involved more. Yeah. Sometimes we are trying to think what they need, but it is not really what they need. Yeah. Like the doors in the back. Maybe we think it's best to prevent children from touching it, but it's kind of hard for her to get down, bend her knees, and try to reach it. We didn't really talk to her.

The student designers in this category involved the users in exploring and understanding the needs and broader context and incorporated that information into the design. For example, for her design for the local childcare center, Paige spent time both interacting and observing the children in the childcare classroom they were designing for and incorporated that information into the design.

We visited [Childcare Center], and we spent some time with the kids, so trying to take that experience and then working it into the model, things like that...We just kind of talked to them. We watched them. The teacher had activities that she was doing with them, so we watched them with the activities to see how they would respond, and these kids were brilliant.

Students in this category described experiences that challenged the assumptions they had made in the design process and gave them not only an understanding, but a commitment to the belief that it is very important to involve the stakeholders in the process, which represented a more comprehensive way of experiencing human-centered design.

**Category 7: Empathic Design**

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. Critical variations between category 6 (Commitment to Involving Stakeholders to Understand Perspectives) and category 7 (Empathic Design) were the strength of the connection with the users and the breadth and depth of the understanding of the context. This is illustrated by David's discussion of how he spent social time together with his users and the use of the language of the users.

We would sit down, have lunch, share some stories, talk about just what's going on in our lives and what we've been up to, maybe get a couple of stories from across the pond in Iraq or whatever, come back to the office, and we would sit
down and they would just say, “So have you been working on, perhaps, your mapping software that you are working with?

This is also illustrated by William when describing that at first he saw the people he was designing for very objectively, but by spending time with them and learning about them, the people became real.

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.

In addition, the student designers in category 7 wanted to understand the people in a broader way than those in category 6. For example, the student designers of category 6 sought to understand the context to inform the current design, as illustrated by Andrew in category 6 who was designing a device that would be used in critical care situations. Andrew wanted to know information about the stress that the nurses would be in when using the device and what would be going through their mind so as to inform the design:

…so we really questioned her on what’s the situation like for the nurses in a critical care situation? Is it high stress? Those kinds of things. What kind of things are the nurses looking for? What could be beneficial for his/her interactions with the patient or his/her ability to do their job? …this is going to be used by people every day, and so the information she gave us concerning the things that are going through nurses' minds and how busy they are and how they don't seem to have enough hands, we really incorporated that into altering our design.

Whereas the student designers of category 7 sought to understand their stakeholders’ personal motivation and dreams, their cultural, and the political factors—factors that will impact the future needs. For example, Maddie described how the government-sponsored development will affect the need for water and their solutions for addressing the need.

We interviewed people to determine water usage, like how much water do you use for cooking, how much water do you use for bathing? Do you have flush toilets? Are you going to get flush toilets? That’s one thing that was really interesting was they’re in this period of development. The government just provided money for people to update their homes, and they’re giving money away, saying “Get flush toilets, get showers and stuff,” but they’re already short on water. So when they add flush toilets and showers, they’re literally going to just deplete their water resources like that (finger snap). So that’s something we’re looking into: not only implementing a system that works, but encouraging them to have more sustainable practices.

Furthermore, the student designers in category 7 based their design on knowledge gained through their connection with end users, not on preconceived ideas and assumptions. This was illustrated by David when he realized that he could not base his design on what he thought would work.

We did several things at the beginning that seemed like a great idea to us that when they saw it, they went “We can’t use that on the battlefield. We’re holding a gun. There’s no way we can double click or multi-click on this thing. It just doesn’t
work. We're holding a gun, so it has to be one click and possibly something that we don't even have to take our finger off the gun for." We knew we couldn't even imagine what they were going through, so they had to provide us with that information; they had to tell us what they needed. I think that was very important.

In summary, the student designers whose experiences comprise this category understand human-centered design as Empathic Design. They developed a very broad understanding of stakeholders beyond scope of project, interacting with users informally and in social situations. They based their design on knowledge gained through a connection with end users, not on preconceived ideas and assumptions or on a limited understanding of the user typically achieved with a single interview. The experiences of category 7 represented a more comprehensive way of experiencing human-centered design than those of category 6.

The outcome space resulting from this study on the ways human-centered design has been experienced by students in the context of "designing for others" contributes to the current understanding of human-centered design and has implications for design education. The following sections provide a discussion of the outcome space, both as it relates to the literature as well as implications for design education, the limitations of the study, and future work.

**DISCUSSION**

The overall structure of the outcome space, consisting of the nested hierarchy of categories 3 through 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 (2006) framework of human-centered design. Second, the graph of categories 3 through 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 also what are the typical pathways of development towards that more comprehensive experience. Because the space represents a developmental model, the different categories do not map onto the spaces (such as Sanders’ 2008 model) of design practice and design research as a whole. However, the most comprehensive category 7 (Empathic Design) does reflect a more participatory approach within the human-centered design space.

Threshold Concepts

The framework of threshold concepts (Meyer & Land, 2003) also provided insight to aspects of the outcome space. The categories which emerged reflected a need to overcome certain threshold concepts to develop more comprehensive ways of human-centered design. The concept of thresholds was most helpful in considering 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). However, 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) demonstrated transformative aspects in students’ experiences of human-centered design.

Experience

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 whose 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. This is illustrated by the quote from Sejal (category 6) describing her experience in which her prototype was rejected by the patients as a “wake-up call.” Similarly, all the student designers whose experiences comprised the “Empathic Design” category described immersive experiences with their stakeholders, particularly the users. For example, 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.

The idea of critical experiences as allowing the students to experience human-centered design in more comprehensive ways is a very important one, especially related to design education, and requires further study. Some aspects to explore are: what defines a critical experience and what roles do critical experiences have in the learning of human-centered design.
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, Andrew (category 6) 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.

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?

The fact that the students learned as a 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 (Bransford, Brown, & Cocking, 2000; Bringle & Hatcher, 1996; Clayton, 2010). However, because the relationship of reflection to the different experiences was not the focus of the study, several interesting questions as to the role that reflection did play in developing the ways of experiencing that the students described, or what role it could play in developing their understanding of human-centered design remain. These are important questions related to design education and require further study.

Human-Centered Design Ideas

Several students described how being introduced to human-centered design concepts as part of a curricular experience brought a new way of thinking about design. For example, Gina (category 4) stated that “I didn’t think in terms of user-centered design when I came to college. You just think an engineer designs things.” This suggests that human-centered design concepts may provide a very different way of thinking about design for some students. From an educational point of view, it may be important that these concepts are explicitly addressed when talking about design because it appears that students do bring preconceptions 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. For example, although Sejal’s experiences were included as category, 6, she defined human-centered design as “something that immediately affects humans.” Her definition reflected a narrow scope of human-centered design as designing only things that positively helped people and this definition lacked the depth of the experience of human-centered design which she had described. This suggests that it is important to not assume that students understand what human-centered design means even if they are familiar with the phrase itself. It is also important as a researcher exploring the students’ experiences or understandings 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. Because the focus of this study was on understanding the variations in the experiences themselves, this required that aspects related to the reasons for those variations initially be ignored. However, exploration of those relationships and impact of the different contexts would provide tremendous insight and inform design education.

One aspect of the context which offers opportunities for exploration is the impact of the academic context on the experience of 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 (2008) 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.”

Another area of context to explore is how the students perceived various experiences and the impact of their perceptions on their learning. For example, the students talked about the “reality” 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.

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.

In addition, this study was situated in an engineering context. Most of the students who participated in the study were engineering students, so the findings represent variation primarily of engineering students’ experiences. However, this work lays a solid foundation for future studies that would include architectural design, product design, and other design students.

In addition, the exploration of human-centered design began with the student’s reflection on an experience “designing for others.” This prompt could limit the responses if the students did not view their design experiences as fitting within that context. However, as noted in the previous section, using the term “human-centered design” would also have limited and biased students’ responses because of students’ unfamiliarity with the term and misconceptions about the meaning of the term “human-centered design.”

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:

• Are there experiences that are “critical” in the learning of human-centered design for students? If so, what are the characteristics of those 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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APPENDIX A: INTERVIEW PROTOCOL

After an initial version of the protocol was developed, the protocol was piloted with students who were representative of the population. In the pilot, both the protocol and the interview techniques were critiqued and revised with the project advisors and an expert in phenomenography. This was an extremely important part of the process. The review helped identify types of follow up questions that could unintentionally suggest a valued activity or response, and alternate ways to probe that aspect of the experience. This process helped identify key phrases in which to follow up on. For example, the following was an excerpt from one of the pilot interviews:

Participant: Yeah, we wanted to make her happy when we were working on the design. She had mentioned that it's really got to be aimed for K-12, but we want it to really have this . . . we want to redefine what engineering is, because we're not getting enough diversity in our engineering groups, and we want to make sure that we're attracting people that may not choose engineering as their first degree.

Interviewer: Did you meet with her?

Although it is subtle, asking the question “did you meet with her” suggests a preference for a particular type of interaction. Instead, the following probing question was recommended: “What types of interactions did you have with her?” In addition, phrases such as “wanted to make her happy” were identified as aspects that should be probed in more depth as it relates to the participant’s understanding of human-centered design. Based on the review, changes were made to the protocol, and strategies were developed to identify and appropriately probe relevant aspects in the interview. In addition, the first two interviews of the study were scheduled to allow time to review the transcript before the next interview to fine tune the protocol and interview technique before continuing. Once that was done, the interviews were conducted without additional review or analysis of the protocol or technique with one exception. Many of the students had difficulty with the question “What human-centered experiences did you use in this experience?” because they could not identify specific human-centered design concepts. However, when changed to “Do you think this design experience is an example of human-centered design?” the students were able to respond to that question with specific ways in which they believed the experience was or was not an example of human-centered design. The final interview protocol is given on the following pages.

Opening Statements:
- Thank you for agreeing to participate in this study.
- Who: I am interviewing students who have participated or are participating in designing projects for others.
- What: Research study exploring students’ experience of human-centered design for my dissertation project.
- Why: Results will be used to help future education of designers, as well as to further discussions generally about human-centered design.
- When and How: One interview of approximately one hour, which will be audio recorded so I can focus on listening. It will be transcribed later.
- Confidentiality - the interview will be de-identified using pseudonyms for any reports from the study, only myself and my research team will have access to the recordings.
• Your participation is completely voluntary, and you can stop at any time.
• There are no correct answers, I am only interested in your experiences.

Background Questions:
• What year are you in school? What is your current major? Have you always been in that major?

Describing Experiences:
• Can you describe an experience you have had that involved designing for others, which I am calling “human-centered design”?
  o Tell me what you did in the project?
  o What was the goal/what were you designing?
  o Who were you designing it for?
  o How did you approach the task from its beginning to its current status? Please walk me through the way you went about doing human-centered design?
  o What led you to do things in that way/why did you do that/How did you decide to do these things?
  o In what way was the [user/client/customer/stakeholder] involved in the design?
    • How often did you interact with [user/client/customer/stakeholder]?
    • What did a typical interaction with the [user/client/customer/stakeholder] involve?
    • What kind of information were you trying to learn?
    • Why was it important to have that particular information?
    • What did you do next after you met with the [user/client/customer/stakeholder]?
    • Where were all of the places that you met with your [user/client/customer/stakeholder]?
  o What influence do you think the user had on this process?
  o How did you incorporate info from user into your design/design process?
  o How far did you get in the design? Delivered?
    • If delivered project: what was your experience in delivering the project to the [user/client/customer/stakeholder]?
    • What feedback did you receive? Who did you show the design to?
    • If comment on relationship with user, or that communication on team was easy, aesthetics, safety, whatever…how important do you think your (whatever) is for human centered design? Can you give a specific experience where you have done that?
    • Do you think this design experience is an example of human-centered design? If “Yes,” in what way? If “No,” why not?

Other Experiences: If yes, probe with questions above
• Can you describe another experience you have had that involved designing for a [user/client/customer/stakeholder]?
  o How do you think this is different from the experience we talked about earlier?

Summative Questions:
• Based on what we have discussed, what would you say human-centered design is? [NOTE: Does that match with how they talked about their experiences? If different, probe that.
• When you think about doing human-centered design, what does that mean?
• How would you describe the relationship between the designer and [word used] in human-centered design?
• As designer, what things are important to think about when doing human-centered design?
• How have your views of human-centered design changed?
• Please describe any experiences you had that challenged your way of thinking about human-centered design?
• Reflecting back on your experiences, if you were to change anything related to human-centered design, what it would be?
  o Step through each experience
• Exploring the different words used to describe people:
  o If used different words for people: you have used words “user,” “client,” or whatever? Do words have similar or different meanings to you?
  o If didn’t: various words are used to describe people in human-centered design: user, client, customer, stakeholder. Do words have similar or different meanings to you?

Exploring Relationship to Experiences:
• What experiences do you believe contributed the most to your understanding of human-centered design?
• Anything else that you want to add about your human-centered design experiences that you do not feel like I have asked about already?
• Follow up with any aspects that they did not talk about earlier.

Concluding Questions:
• What are your questions of me?
• Thank you for your time!!!