

Design Ethnography in Capstone Design: Investigating Student Use and Perceptions*

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In today's global markets engineers need to design products for a wide variety of stakeholders and cultures. Engineering students, therefore, must learn how to design products that meet the needs of the stakeholders and are appropriate for the cultures in which they will be used. Human-centered design guides students in developing design ideas that achieve this goal. This approach has proven to support innovation, increase product uptake, reduce errors, and focus the design on the user experience in addition to product functionality. Design ethnography is an important component of human-centered design and has been shown to be effective for understanding the true, and sometimes hidden, wants and needs of stakeholders and for informing design decisions. While the utility of design ethnography has been promoted within business and product innovation literature, student learning of design ethnography techniques has lacked study. This exploratory study sought to address this gap by characterizing the ways students use design ethnography methods during a capstone design experience as well as their perceptions of these methods within their design projects. Design report documents and semi-structured interviews were used to explore student practices and perceptions. Students used various design ethnography techniques including interviews (both structured and semi-structured), informal conversations, observations, and surveys. These were used throughout the design process (from problem definition to testing and validation), however, the methods were most frequently used when defining the problem, developing user requirements, and translating these into engineering specifications. Although there were numerous instances of successful uses of design ethnography, the focus of this study was on obstacles encountered when implementing these techniques to inform their design decisions. Semi-structured interviews revealed that students perceived both benefits of and frustrations with using design ethnography. However, the benefits that students perceived were often superficial in nature and the frustrations they encountered often stemmed from the challenges associated with open-ended problem solving. The results illustrate the need for the development of effective tools and pedagogy to support students when learning and practicing design ethnography.

Keywords: design ethnography; human-centered design; user-centered design; design pedagogy; immersion; capstone design

1. Introduction

Numerous reports have called for engineering students to develop the ability to design innovative solutions to today's increasingly complex problems [1–3]. Truly innovative solutions are not only creative, but also practical in the context of a culture and its people [4]. To meet modern challenges, the engineering design field has expanded from a function-centered view to include a human-centered (sometimes referred to as user-centered, although some make distinctions between the two approaches [6, 7]) view of design processes, where the focus is on developing the full experience between the user and the product [7]. In a review of human-centered design definitions, Zhang & Dong characterized human-centered design as having an emphasis on the individuals involved, developing a holistic understanding of them, involving all stakeholders during all design phases, and developing useful,

usable, and desirable products [8]. A human-centered view of design encourages designers to prioritize the needs and wants of the user. However, developing this understanding and applying it to the design process requires the use of systematic methods. One such method is design ethnography.

Design ethnography evolved from the ethnographic techniques developed by anthropologists [9]. Adapted for use by design engineers, design ethnography attempts to understand and represent the perspectives of daily life and defines approaches for understanding the actions, words, and thoughts of users and stakeholders in order to inform design decisions [10–13]. Design ethnography data collection includes observing users while they interact with products of interest or as they go about their regular activities in a particular environment and interviewing users and stakeholders about their priorities, experiences, and preferences. Another important aspect of design ethnography is the use

of the collected data to inform design decisions relevant to users and stakeholders as well as the broader design context.

Design ethnography methods can be used throughout all phases of the design process including defining the problem, understanding the voice of the customer, translating the voice of the customer into requirements, generating solutions, and developing and evaluating the end-product [14]. A key advantage of design ethnography methods like observations and in-depth interviews is that designers have the opportunity to discover needs and problems that are not otherwise obvious to the designer or even the user. Users accustomed to performing a task in a particular manner may not be conscious of the problems or deficiencies and therefore may not be able to express these problems when outside of the environment of use. By placing the researcher into the users' environments and exploring the ways the users engage in daily life, design ethnography data collection methods can remove biases and pitfalls of self-reporting, because they allow direct examination of users' potential needs. In addition to allowing the design engineer to explore human-device interface constraints, design ethnography enables consideration of the potential device's emotional, psychological, cultural, and social impacts, which are too rarely discovered via traditional market research. Another key feature of design ethnography in a global marketplace is its ability to bridge gaps between cultures and allow designers to obtain tacit knowledge relevant to product design [15]. The importance of obtaining cultural understanding of a target market to aid in product design has been increasing as firms try to design for particular cultures that are different than their primary market [16–18]. Products that are successful in one context may fail to be adopted in another due to cultural differences. As an example, one can look at the failure of Kellogg to effectively penetrate the Indian market because they didn't fully understand the habits and preferences of Indian customers during breakfast [19]. Indian consumers traditionally make their own breakfast in the morning or consume biscuits and tea; breakfast cereals have not historically fit into Indian consumer habits.

One early documented use of design ethnography sought to increase the usability of products manufactured by Xerox. Observing customers' use of copy machines in actual office environments led the firm to develop instructions that guided users systematically through problems like paper jams [20]. Design ethnography also plays an important role in the design of software interfaces where the abilities and skills of software engineers usually far exceed those of a typical user; design ethnography

helps bridge the gap between the expert user who designs the software and the typical customer who eventually uses the software [9].

Design literature has documented various approaches to design as well as novice to expert trends in executing design skills [21–24]. However, while the benefits of design ethnography have been discussed within business and product innovation literature, few studies have focused specifically on the development of student design ethnography skills. Prior work has intimated that students have difficulty performing design ethnographic investigations and incorporating the results into their designs. In a study of graduate student designers, Sugar found that the students' designs changed little after performing usability testing and engaging with users [25]. Even though the students claimed that usability testing was a beneficial tool, it failed to lead to major changes in their designs. Students tended to focus on overt usability problems faced by the users and were not able to identify the underlying issues that led to those overt problems. In a study of user engagement as part of a technical writing course, Scott discovered "tensions" between students' preconceived notions of the value user engagement and their practical difficulties with implementing user engagement [26]. As their design projects progressed, students became more aware of the complexities involved with significant user engagement and responded by minimizing the ways in which they interacted with users. In a study characterizing students' understanding of human-centered design, Zoltowski developed a framework that described how student designers experienced human-centered design work, representing less comprehensive understanding, i.e., complete lack of appreciation for stakeholders, to more comprehensive understanding, i.e., developing significant relationships with stakeholders [27]. While these studies provide valuable insight into students as design ethnographers, there are still many unknowns in the process of developing students from novices to more informed design ethnographers. Our study was motivated by this lack of research on the learning process as well as by industry's increasing use of design ethnography.

2. Research design

2.1 Study purpose

A thorough understanding of how engineering students currently perform design ethnography and how they subsequently incorporate the information gained into their design processes is needed if engineering programs are to develop effective pedagogy in this field.

Table 1. Team composition and capstone design course projects

Team	Demographics	Immersion Program Experience	Capstone Design Project
Team A	4 male, mechanical engineering	Yes	Surgical device for middle-income country
Team B	1 male, mechanical engineering 1 female, mechanical engineering 1 male, biomedical engineering 1 female, biomedical engineering	Yes	Diagnostic device for low-income country
Team C	3 male, mechanical engineering	No	Surgical device for middle-income country

Our study was guided by the following research questions:

1. What design ethnography methods do students use to help them make design decisions?
2. What perceptions do students have on the values and challenges in using design ethnography techniques?

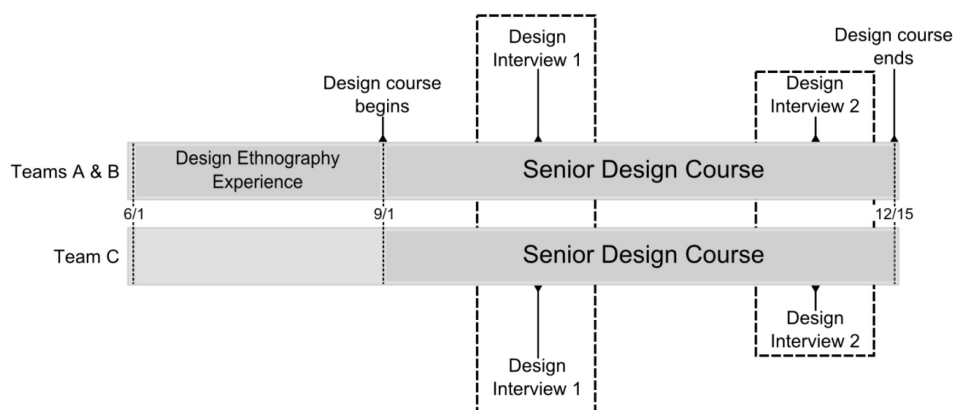
To address these research questions, we used a small number of design teams and a qualitative approach [28–32]. Qualitative approaches provide important insights into engineering education and gathering rich and detailed data is particularly appropriate for an exploratory study [32]. The study was approved by the Institutional Review Board of the University of Michigan.

2.2 Participants

Three different student design teams, which we termed Teams A, B, and C, participated in our study. Table 1 describes their composition. All participants were senior undergraduate engineering (mechanical or biomedical) students. The mechanical engineering students had a minimum of two previous design/manufacturing courses, while the biomedical engineering students had not necessarily taken a specific design course. During the course, Teams A, B, and C worked in groups of four to design a medical device for use in a low- or middle-income country using a divergent-convergent

design process that included the development of user requirements and engineering specifications, concept generation, concept selection, engineering analysis, prototyping, and validation.

During the summer prior to their capstone design course, Teams A and B participated in an eight-week immersion program in one of two low- or middle-income countries, where they conducted clinical observations and interviews in hospitals and/or clinics. Their goal was to develop at least 100 need statements, one of which became the basis for their capstone design course. Upon deciding on a need statement, the students proceeded to develop user requirements using observations, interviews, and surveys during the remainder of their immersion experience. This experience forced Teams A and B to employ design ethnography extensively during the front-end design phases (prior to the beginning of their capstone design course). Further details of this immersion experience can be found in previous publications [33–35]. Team C did not participate in an immersion experience prior to the capstone design course. Inclusion of three teams with different levels of exposure to design ethnography provided diversity with respect to their experiences during the capstone design course. For example, students on Teams A and B interacted with significantly more stakeholders (on the order of hundreds) than the students on Team C (on the order of tens).

**Fig. 1.** Timeline depicting semi-structured interview schedule.

2.3 Data collection

The primary data were collected through two semi-structured interviews with each of the three design teams. Team interviews were conducted at the midpoint and endpoint of the teams' design processes; each interview lasted approximately one hour. Fig. 1 shows the timeline of design interviews with respect to the course.

As part of the course requirements, Teams A, B, and C delivered four reports throughout the semester detailing the work accomplished. The study team analyzed the reports in order to characterize student use of design ethnography and extract the major decision points encountered during the design process. Decision points were defined as junctures during the design process when design teams considered multiple options or when a single option was presented with some form of justification. These decision points became the major topics of discussion during interviews. For example, the major decision points discussed during the first interview were related to user requirements and engineering specifications developed by the design teams. The major decision points discussed during the second interview included design concept iterations, changes to user requirements and/or engineering specifications, and modifications to their design plan as a result of validation testing. During both interviews, decision points were used to guide the discussion and elicit information about how students used design ethnography to inform decisions. When a student mentioned the use of design ethnography in making a decision, extensive follow-up questions were asked to determine what methods were used, how the methods specifically led (or did not lead) to a decision, and how effective or useful the students thought the methods were. This interview protocol allowed the study team to probe

students' use of design ethnography while avoiding leading questions that might imply the utility of design ethnography at decision points.

Table 2 lists example questions that formed the starting point for longer discussions of each team's design process. These questions were based upon the decision points identified during the design report analysis and developed to determine the inputs and outputs of students' decisions. Interview questions were discussed among the research team in order to ensure clarity, suitability, and to ensure that questions were not leading. Table 3 lists example follow-up questions that allowed the study team to gain a deep understanding of each design team's use of ethnographic methodologies. All interviews were audio recorded and transcribed for analysis using Nvivo 10 [36].

2.4 Data analysis

We used an iterative inductive coding procedure during data analysis. Theme identification followed guidelines established for analysis of semi-structured interview data [28]. The inductive approach requires that themes emerge from the data and therefore, preconceived themes were not specifically identified, consistent with how Strauss and Corbin describe emergent theory [37]. The analysis sought to identify the students' perceptions of design ethnography, as opposed to the study team's perceptions of the students' use of design ethnography. The first round of coding consisted of identifying all references about or related to collecting, synthesizing, or applying ethnographic information. The specific design ethnography methods used and the types of decision points to which they were applied were noted and used to characterize student practices. Additionally, the exploration of similarities and differences among the coded segments revealed

Table 2. Example questions asked of design students during interviews

After having developed the long list of need statements, how did you decide which would be your top choice?
How did you decide which user requirements you would include? What led you to these requirements being the most important?
It seems you had difficulty developing engineering specifications from user requirements, what aspect of this task was difficult? What resources were most helpful in overcoming this challenge?
Which user requirements provided the biggest challenge to develop? How did you overcome this challenge and what resources did you use?
Which engineering specifications were the most difficult to quantify? How did you overcome this challenge and what resources did you use?
What information sources did you use during the course of making this decision? Which one was most helpful? How did you know you were making the right decision?
How has your design changed during the course of the semester from its original conception? What prompted these changes?
What caused you to decide on this course of action?

Table 3. Example follow-up questions used to explore students' use of design ethnography

What information did you gain from this interview? How did you use it? Was it different from information you had previously obtained?
How did you conduct the interviews? How did you prepare for the interview?
How important was the information that you obtained during the interviews? How did it influence your decision?
What was most difficult about incorporating stakeholder information into your design process?

two overarching categories: student-perceived benefits of and frustrations with design ethnography. Within the two overarching categories, we explored similarities and differences among the data in order to identify themes, labeled each theme with a description, re-read each data group related to the themes, and made changes where necessary. The procedure was repeated until changes ceased to be made.

3. Findings

The results of the qualitative analysis are presented below in two sections. First, the design ethnography methods students used and the design scenarios in which they were applied are presented. Second, students' perceptions about their use of design ethnography are presented.

3.1 Student uses of design ethnography

Students used a variety of design ethnography techniques in order to inform a host of different design processes during the capstone design course. Table 4 provides a summary of the design ethnography techniques used by design teams and the scenarios in which they were used. Students identified several design ethnography techniques that helped them to make decisions including both structured and semi-structured interviews (with various stakeholders), informal conversations, observations, and surveys. Observations were used almost exclusively during the immersion experience (Teams A & B) for problem definition while interviews were used throughout the entire design process. While all these methods were used at some point during the design process, teams relied more heavily upon interviews (especially with experts) during the capstone design course. Identifying why this preference materialized was outside the scope of this study; however, preliminary results from the semi-structured interviews with the student teams indicated that availability, ease of communication, efficiency of gaining information, and confidence

with the information gained from experts may have played a significant role in this preference.

Design ethnography played a significant role in decision making during a variety of different design scenarios during the capstone course (Table 4). It was used extensively during the front-end design phases (i.e., problem definition, understanding product environment and usage, identifying user requirements, and developing engineering specifications). While the collection of data using design ethnography decreased after the front-end design phases, students continued to use the data previously collected and collect more data (to a lesser extent). Although there were numerous instances of successful uses of design ethnography, the focus of this study was on obstacles students encountered when implementing these techniques to inform their design decisions.

3.2 Student perceptions of using design ethnography

While the results above provide preliminary findings as to the design ethnography methods students chose to employ and the situations in which they were employed, this study also sought to determine how students perceived their use of design ethnography. These student perceptions are displayed in Table 5 and the themes identified were placed into two overarching categories: student-perceived benefits and student-perceived frustrations with using design ethnography. An in-depth discussion is presented below.

3.2.1 Student-perceived benefits of design ethnography

Themes representing student-perceived benefits of design ethnography included gaining information from stakeholders that led directly to design decisions and receiving explanations from stakeholders on technical issues. Students consistently cited stakeholder interaction as the source of the most useful

Table 4. Design ethnography techniques used by students during the capstone course and the scenarios in which they were used

Design ethnography techniques used	Scenarios in which design ethnography was used
Interviews (structured and semi-structured):	Identifying/understanding/defining the problem
– with experts	Understanding the environment/product usage
– with stakeholders	Gaining background technical knowledge
– with end-users	Identifying user requirements
– with proxy end-users	Developing/refining engineering specifications
Informal communication/conversations	Ranking user requirements
Observations	Understanding an unfamiliar field
Surveys	Developing testing/validation methods
	Confirming information/decisions
	Understanding ergonomics
	Guiding design decisions
	Guiding design principles (i.e. simpler is better)
	Evaluating concepts and approving final designs
	Conducting usability testing/validation

Table 5. Themes found after analysis of interview data

Overarching Categories	Student-perceived benefits of using design ethnography	Student-perceived frustrations with using design ethnography
Themes	Gaining information from stakeholders led directly to making design decisions Receiving explanations for complicated and technical information quickly and easily from stakeholders	Receiving inconsistent information from stakeholders Stakeholders could not specify user requirement Finding the “right” stakeholder to interview

information during design decisions as well as a source of clarification during difficult and technically complicated portions of the design projects. The two primary themes in this category and excerpts from team interviews are presented below.

Theme: Gaining information from stakeholders led directly to making design decisions.

Teams A, B, and C consistently voiced the opinion that interactions with experts and stakeholders produced very useful information for design decisions. Decisions affected by expert and stakeholder interaction included determining which user requirements and engineering specifications should be included, rank ordering these requirements, evaluating concepts, and developing validation procedures. When design teams faced critical decision points, they frequently found the answers during their interviews with stakeholders.

During a discussion on obtaining user requirements and engineering specifications, Team B was asked which sources of information were the most useful and relevant when obtaining the requirements and specifications:

“People . . . Interviews. That’s where we got the best [information]” (Team B, 1st Interview).

Team A’s project involved assessing environmental hazards; this is how they described their interaction with an expert in this area:

“[The expert] was extremely helpful to us. . . From OSHA [Occupational Safety and Health Administration] . . . She taught us about the dragger tubes. We had no idea dragger tubes even existed . . . And I think we figured out that sometimes online research is kind of hard for some knowledge, like the dragger tube. We would never know the dragger tube if we didn’t talk to anybody” (Team A, 2nd Interview).

Team A continued to emphasize the importance of interacting with experts when seeking to understand key engineering issues. They mentioned experts who helped them through difficult aspects of the design process:

“I feel like it was a lot more helpful to actually talk to people who are specialists in the field . . . once we started talking to [the manufacturing engineers] . . . they were able to answer a lot of questions we just couldn’t find online” (Team A, 2nd Interview).

Team A considered their interaction with manufacturing experts essential as they tried to develop a successful design.

Team C spoke about the usefulness of both viewing an actual procedure in which their device would be used and speaking to stakeholders having the most knowledge about the current devices in use:

“We actually went into the open heart procedure and [the surgeons] . . . showed us how all of the equipment works together, so we got a better feel for what they are expecting in terms of like the size and . . . the shape. . . how it could fit in [and] especially be held.” (Team C, 1st Interview).

During interviews, all three teams commented that they gained valuable information from stakeholders that led directly to design decision.

While students pointed to interaction with stakeholders as a key source of decision-making information, the students did not speak to any examples where they gained tacit knowledge from stakeholders. Instead students focused on using interviews with stakeholders to solve problems outside their domain of expertise.

Theme: Receiving explanations for complicated and technical information quickly and easily from stakeholders.

The second theme in student-perceived benefits was that stakeholders articulated issues and technical jargon in ways that were both tangible and useful. For example, during the early stages of their project, Team C discovered that the specifications provided by their company sponsor did not align with the interviews they had conducted with doctors. They discussed how a single interview was able to clear up the confusion:

“[The company] was very specific too and it took just one good interview with the [doctor] at the hospital [to obtain the correct specification]” (Team C, 1st Interview).

Team B described multiple times when experts or stakeholders helped steer the team in the correct direction:

“It was [the electrical engineering professor who said] ‘maybe you want to cascade two [filters] in line’ . . . so that planted the seed and I found a Butterworth [filter]” (Team B, 2nd Interview).

The same team summed up this trend during the project:

“It’s a general theme of how we have done everything with this project. People point us in the right direction and we try to research it as much as we can” (Team B, 2nd Interview).

Team A had no experience in the medical field, which led to the challenge of understanding what was happening in the operating room and how the stakeholders helped them to understand:

Student 1: “We also talked to other medical personnel, such as setup people and nurses.”

Student 2: “They weren’t . . . interviews. More like quick talks. They helped explain to us what was going on because one of the challenges was we’re all mechanical engineers, we’re in an operating room, and we don’t know what they’re doing” (Team A, 1st Interview).

At various points in their design processes all three teams made reference to the theme that experts were able to explain highly technical information to them in a way that enabled them to easily incorporate the information into their design processes.

When interviewing stakeholders on technical topics, students appeared to be able to extract information easily from stakeholders and explore ideas thoroughly. We believe that this could be due to the very specific topics around which these interviews were based. For example, when interviewing professors who were experts in signal processing, Team B was able to gain valuable information with respect to how they should approach their problem. Students were using the interviews to circumvent the task of reading and learning about a field as broad as signal processing.

3.2.2 Student-perceived frustrations with design ethnography

The students cited many frustrations related to the use of design ethnography while collecting, synthesizing, and applying stakeholder information. Frustrations were defined as issues and challenges that the students identified as barriers to using design ethnography to make design decisions. The analysis elucidated three themes discussed below.

Theme: Receiving inconsistent information from stakeholders.

The three design teams reported receiving inconsistent or incorrect information from stakeholders. Some stakeholders gave opposing viewpoints on a specific subject, some experts contradicted the literature, and some stakeholders provided conflicting information based upon how students elicited the information, e.g., via surveys versus interviews. The teams had not anticipated the possibility of having to reconcile inconsistent or incorrect information,

which led to difficulties in their decision-making processes.

Team A described their interviews with physicians to elicit the importance of cost for their proposed design:

“Yeah, sometimes they would give us a little bit of mixed views, or mixed opinions. Sometimes the doctors would say that cost is super important and at other times on surveys [cost] would end up being one of the [least important requirements] on the list when we asked them to rank them” (Team A, 1st Interview).

The conflicting information between interviews and surveys was not expected by the design team and the team was forced to reconcile the conflicting information without a particular strategy.

Teams A and B ran into difficulties when quantifying information that was not uniform across stakeholder interviews. Team A described their attempt to define the accuracy of their device in order to establish validation criteria:

“Because what does accuracy mean? Different people will interpret it different ways.” (Team A, 1st Interview)

Team B described a similar issue when developing an engineering specification after interviewing doctors who held different views:

“. . . except that a lot of doctors can interpret variations [in the signal] differently.” (Team B, 2nd Interview)

Teams A and B both found difficulty in attempting to quantify stakeholder information which was not uniform among various interviewees.

The theme of receiving inconsistent or incorrect information from stakeholders was evident during the study team’s interviews with all three design teams. This inconsistent or incorrect information often led the teams to become temporarily “stuck” at a particular decision point. When considering physician opinions on topics, it is natural to expect differing views on how to interpret physiological signals; however, the students believed that there should be only one correct answer to their question and were thus frustrated when presented with varying responses. In general, the students teams lacked strategies to synthesize data to inform specific design decisions.

Theme: Stakeholders could not specify user requirements.

Students were also frustrated because they encountered difficulties while gathering user requirements from stakeholders. This created downstream challenges when they attempted to design a solution based upon these requirements.

This theme is exemplified when Team A reported what occurred when they asked physicians about an engineering specification for the user requirement

related to the maximum allowable size of their device:

“... they didn’t even know what our solution would look like, [the doctor said], ‘well I guess if it is some handheld device, maybe a 50% increase [in size over the current solution]’ ... they were just kind of guessing ... they just ballparked ... which might not have been a good thing for us to aim for, in hindsight” (Team A, 2nd Interview).

The high allowance for size specified by the physicians turned out to be erroneous, and Team A had to adjust their design after prototyping had been performed.

Often, stakeholders could not visualize the design solution; Team A described the difficulty of attempting to gather user requirements from stakeholders without preconceived solutions:

“Well [the doctors] kept telling us to do a specific solution so ... it was difficult to explain that we needed solution-independent user requirements” (Team A, 1st Interview).

During a discussion with Team A related to their development of the user requirement of patient safety, Team A was asked what the surgeons specifically meant by the term “patient safety”:

“I don’t think we specifically asked. [The doctors] just said [safety] was the first, the most important.” (Team A, 1st Interview).

Because Team A did not follow up with the doctors on this issue, they understood only that “patient safety” was an important user requirement, without understanding how it might be translated into engineering specifications. This led to frustration when students attempted to develop engineering specifications based upon this vague user requirement.

Team B described the difficulty in explaining the user requirements to physicians without influencing their answers:

“The biggest problem I had is if you didn’t give them an example of what a user requirement was they wouldn’t know what to tell you, but if you did give them an example of what a user requirement was, they would say ‘oh, yeah. . .that’s what I want’” (Team B, 1st Interview).

Another member of Team B discussed the difficulty in getting doctors to develop user requirements creatively during interviews:

“I found that if you put [options] in front of them when interviewing. . .it would stomp the creativity of the interview. . .they would do it more of like a task than critically thinking.” (Team B, 1st Interview)

This theme was largely found during interviews with Teams A and B, likely due to the fact that Teams A and B developed user requirements in the field during their international immersion experience. The international and clinical setting in which students were working may have exacerbated the

difficulties of developing user requirements through stakeholder interaction.

Within this theme students pointed to the difficulties they faced when attempting to gather user requirements directly from stakeholders: students sometimes elicited user requirements from stakeholders that they later discovered were not appropriate for the design, stakeholders provided vague user requirements, and students struggled to extract user requirements without biasing stakeholders via examples or question structure. Our analysis suggests that students’ lack of experience with interviewing techniques limited the quality of the ethnographic data they obtained.

Theme: Finding the “right” stakeholder to interview.

Within this theme, students spoke of being unable to interview the correct stakeholder. Teams mentioned several reasons as described below.

Team B faced the issue of no longer being able to find the experts needed to answer the questions they had about their project:

“... so the problem with [this physiological] signal now is that there is no such thing as an expert in monitoring [it] ... so we’re at a cross roads where all of the external input that we get, there is not much value in it” (Team B, 2nd Interview).

Due to the specificity of their project, the team believed that they would not be able to find a stakeholder who could answer their questions towards the end of their project.

Team A wanted to solicit a price point for their medical device from surgeons, despite the fact that the surgeons were not formally involved in the procurement process:

“I don’t think the surgeons are the ones deciding to buy it, they’re just the ones who use it, and so they have a pretty good understanding of what [the current products] cost ... but there is no saying that from our interviews with them ... [if] that’s 100% true” (Team A, 1st Interview).

Team C described a situation whereby the information given by US surgeons did not apply to the middle-income country setting they were designing for:

“I think [the American surgeons] are just kind of biased towards smaller devices ... we understand ... their point of view ... but we have been designing for cost, low cost for this [middle-income] market” (Team C, 2nd Interview).

Team C recognized the differences between designing for a middle-income country and the US, but was unable to pose their concerns to US surgeons in a way that would elicit information useful for a middle-income country.

Students reported that the stakeholder they

wanted to interview was not accessible or did not exist; however, the student teams were overly focused on finding a single stakeholder to answer a specific question. Generally, the teams did not consider interviewing multiple stakeholders with varying expertise and synthesizing the information to inform design decisions. For example, Team B believed that an expert in the physiological signal particular to their design project did not exist, however, the team did not consider interviewing physicians (who would have knowledge of the signal) and engineers (who would have knowledge of signal processing) and combining the data yielded from both types of experts.

4. Discussion

4.1 Summary of findings

This study aimed to determine how students use design ethnography and perceive its usefulness when making design decisions. Students employed several design ethnography techniques during various design phases. Interviews with experts were the most common design ethnography technique students employed and were also used throughout all stages of the design process. Availability, ease of communication, efficiency of gaining information, and confidence with the information gained from experts played a significant role in students' preferences for choosing to use interviews.

The thematic analysis of interview transcripts with regards to student perceptions of design ethno-

graphy use resulted in two overarching categories of themes: student-perceived benefits and student-perceived frustrations when using design ethnography. The benefits and frustrations students perceived had significant implications for their decision making processes and this is summarized in Fig. 2.

As shown in Fig. 2, when students perceived design ethnography to be beneficial, their decision-making processes followed two distinct paths, each of which produced what they perceived to be a fully justified decision. The first path involved consulting with a stakeholder and then making a decision based directly on this interaction or after consulting literature made relevant by the stakeholder. The second path represents an initial review of the literature and then consultation with a stakeholder to clarify the findings. While the students effectively used design ethnography data to justify their design decisions, an analysis of the content of these decisions showed that students were not gaining the deep, detailed information that design ethnography data collection can yield.

Also shown in Fig. 2 are three distinct decision-making paths that students followed when they perceived a frustration with design ethnography. These frustrations disrupted their decision-making processes and led to what students perceived to be partially justified decisions. The perceived frustrations with design ethnography seemed to stem from student errors when planning or implementing ethnographic methods or when utilizing the information collected. In the third path, students were

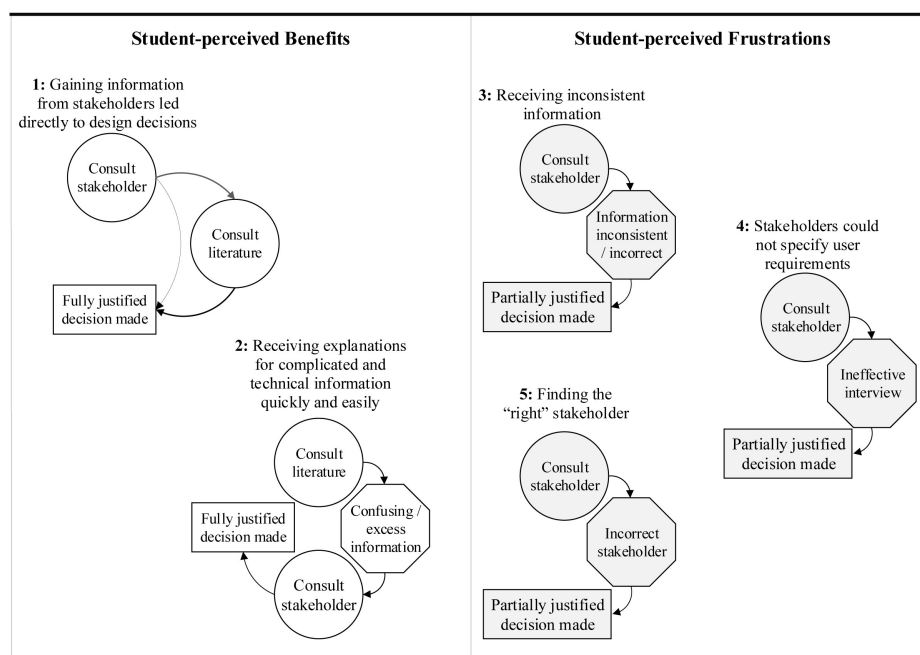


Fig. 2. Decision-making processes followed by student teams when implementing design ethnography.

frustrated when receiving inconsistent information that the study team believes stems from the challenge students faced when synthesizing multiple perspectives from stakeholders and making an informed decision. Conflicting viewpoints are common when interviewing stakeholders on most topics, but students expected each stakeholder to provide similar opinions and this assumption led to difficulties in decision making. The fourth path represents students' expectations that stakeholders would be able to clearly specify user requirements. However, planning and executing effective interviews is a skill learned through experience and time. Students had the unrealistic expectation that stakeholders would be able to list user requirements during interviews, which the students could then directly use in their design projects. However, the role of the designer is to translate ethnographic data into user requirements and engineering specifications, and students struggled to recognize this as their role and how to approach this practice. The fifth path represents students' frustration when they felt they could not find the "right" stakeholder to answer their questions. However, analysis of the interviews and design reports led the study team to recognize that students were actually struggling with the task of synthesizing information collected from multiple stakeholder interviews when making a decision. In general, teams associated each decision point with an accompanying single stakeholder who could answer their questions in order to determine what decision to make. This frustration may stem from the larger problem of students' difficulty with solving open-ended problems that have no clearly defined solution or methodology.

While our intention is not to make claims on the impact of an immersion experience on students' use of design ethnography, in our comparison among teams, we noted some distinctions. Recall that Teams A and B had performed eight weeks of clinical observations and interviews prior to the commencement of the capstone design course, whereas Team C learned about their project during the first week of the course. Analysis of the interview data revealed that all three teams provided approximately equal numbers of examples related to the benefits of design ethnography. However, Teams A and B spoke significantly more about the frustrations involved in using design ethnography. These two teams attempted to define user requirements and engineering specifications during their eight weeks of clinical immersion and thus had more opportunities to encounter frustrations than Team C. Determining whether this difference arose from greater exposure to design ethnography or from the international/clinical setting of the immersion experience is outside the scope of this study. The

small sample of teams interviewed precludes a generalization of the difference between immersion and non-immersion teams; however, our follow-up work will explore this in more depth.

4.2 Characterizing student implementation of design ethnography

The findings discussed above are consistent with the limited research on design ethnography education previously cited. Our finding that students were frustrated with extracting user requirements from stakeholders is comparable to Sugar's finding that students performed only minor design changes after engaging with users and conducting usability tests [21]. Students in our study and Sugar's study performed only surface-level interactions with stakeholders and did not extract the underlying rationale for the stakeholders' responses. Students did not consistently recognize opportunities to perform in-depth exploration of stakeholder knowledge. Similarly, all of our themes of student-perceived frustrations with design ethnography can be compared to the "tensions" found by Scott between students' preconceived notions of the value of stakeholder engagement and their practical efforts to implement it [22]. In our interviews, the students spoke frequently of the challenges and frustrations with collecting, synthesizing, and using stakeholder information. This indicates that as their use of design ethnography increased, students better understood the complexities of stakeholder engagement and the non-trivial process of design ethnography. Their continued use of design ethnography in the face of these frustrations indicates that they also faced tension between the value they saw in using design ethnography and the difficulties associated with its use. In Zoltowski's work students experienced markedly different ways of understanding human-centered design [23], and our findings revealed that students displayed multiple levels of understanding with respect to how design ethnography can be effectively incorporated into human-centered design as they progressed throughout their design work. The frequent references to the benefits of design ethnography suggest that our students understood why stakeholders are included during design; however, the students' surface-level perceptions of the benefits of design ethnography suggest that they did not fully understand these benefits and their frustrations point to their difficulty to achieve those benefits.

Based on the findings from this study, in conjunction with those of the previous studies mentioned above, we propose a model, shown in Fig. 3, of students' desire to use design ethnography as they learn and implement the techniques. The trajectory shows that while students are learning the principles

of design ethnography in the classroom, their desire to implement the techniques increases. Then, as they begin to practice design ethnography in the context of a real design project, they recognize the difficulty and complexity involved, and their desire to incorporate the techniques into their design process decreases. The mix of benefits of and frustrations with design ethnography during design causes their desire to perform ethnographic investigations to rise and fall. The dotted line in Fig. 3 represents the development of expertise wherein a student becomes proficient enough to readily incorporate design ethnography into the design process. A key goal of our design ethnography curriculum should be to provide students with the support necessary during the practical learning phase to speed them towards the point at which the benefits outweigh the frustrations of design ethnography.

4.3 Pedagogical implications

The findings from this study point to aspects of design ethnography that present large obstacles to students, and thus where effort in developing pedagogy should be placed. Conducting effective interviews, recognizing opportunities to involve stakeholders, synthesizing large amounts or conflicting information, and identifying the correct stakeholders to approach are all areas in which students struggle.

Specific instruction can be developed based on the findings presented in this paper. For example, some students did not recognize in time when they were interacting with stakeholders ineffectively or only at a surface-level. Realization did not occur until they attempted to use the information in the context of their design project, when the opportunity to perform follow-up stakeholder interaction was limited

or no longer available. This delayed realization of ineffective implementation did not allow for students to learn from their mistakes and try again. Thus, a real-time feedback mechanism and reflection on interview quality could help students recognize mistakes early and improve their stakeholder interactions. Additionally, it is important to consider how the structure and timing of the course encourages and facilitates students' use of design ethnography techniques. Since perceived design values of the instructor and course format impacts student design choices [38-40], if design ethnography techniques are not emphasized or assessed, students may not recognize their importance and either apply the techniques less rigorously or not at all. Developing pedagogy and course structures to counter the other ways in which students were frustrated with design ethnography shown in this paper may provide the support necessary to move students from novice to more informed practitioners of ethnographic techniques.

4.4 Limitations and future work

This study focused on an in-depth exploration of three engineering student design teams learning and applying design ethnography throughout their design projects. While a study of three teams is not generalizable, qualitative research aims for transferability, which means that the findings are rich descriptions of a specific context, and this rich description can be used by other researchers to make connections to their own situation [41, 42]. The immersion experience that Teams A and B participated in prior to the capstone design course heavily focused on front-end design phases and the teams were actively encouraged to use design ethnography. This may have potentially biased interviews

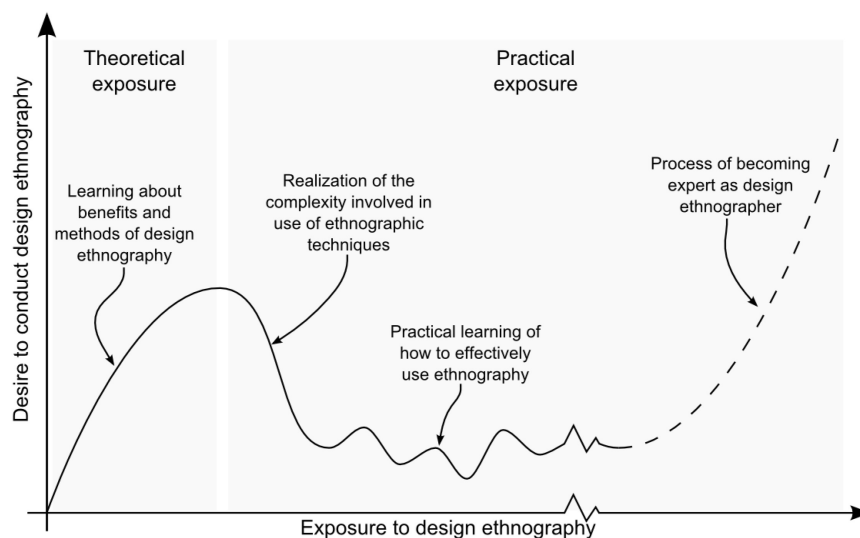


Fig. 3. Model for student desire for using design ethnography.

by focusing on these phases of design. This study was limited by a focus on design decisions rather than the design process as a whole. Thus, while the semi-structured interview methodology allowed for the discussion of a wide range of uses of design ethnography, some experiences with design ethnography not related to decision making may have been overlooked. In addition, team-based interviews did not allow us to fully explore each student's individual perspectives on the use of design ethnography. In addition, the focus on capstone design teams cannot be generalized to professional engineers practicing design ethnography.

5. Conclusions

Design ethnography is becoming more prominent in product development. Case studies highlighting the benefits of design ethnography within industry have been investigated, however, little work has been performed on understanding how students learn and apply the principles of design ethnography. This study expanded upon previous literature by investigating student perceptions of the use of design ethnography when making design decisions. Semi-structured interviews, using a group interview format, were conducted with three senior capstone design teams on two occasions during the semester. Interview questions centered on the various design decisions that students made over the course of the project were identified by analyzing design team reports. Analysis of the interview transcripts led to the development of themes within two overarching categories: student-perceived benefits of design ethnography and student-perceived frustrations with design ethnography. The benefits of design ethnography reported by the students themselves suggest that students can gain a certain comprehension level of design ethnography via practical implementation, but students will require further support to move past the surface-level benefits of design ethnography that were found in this study. Trial and error allowed the teams to discover that ineffective implementation of this complex skill often produces unforeseen obstacles and frustrations. Themes related to the frustrations students perceived when implementing design ethnography were prominent within the data and represent multiple areas wherein design pedagogy can be developed to support learning and implementation strategies.

These results informed the development of a proposed model for students' desire to use design ethnography, where the trajectory is characterized by an initial phase of theoretical learning followed by a practical phase of implementation wherein students face unforeseen obstacles and realize the complexities involved. While the active learning

environment created by a design project allowed students to gain experience and knowledge in the use of design ethnography, more focused pedagogy appears to be needed to move students along the continuum of novice to more informed design ethnographers. Students were challenged by the open-ended nature of design ethnography techniques and specific difficulties related to implementing these techniques. Developing pedagogy to help students conduct more effective interviews, be able to recognize opportunities to involve stakeholders, synthesize large amounts or conflicting information, and to identify the correct stakeholders for their design task would significantly improve students' perceptions of design ethnography and the outcomes of their design projects. Limitations of the current study include the small sample of design teams studied (making it difficult to generalize the results) and the focus on design decisions (which may have allowed uses of design ethnography unrelated to design decisions not to have been captured during interviews). Further research is needed to determine design ethnography pedagogy that best supports student learning.

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