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Assessing Needs in a Cross-Cultural Design Project: Student Perspectives and Challenges*

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Effective identification and evaluation of stakeholder needs is an important part of cross-cultural design projects that greatly increases the likelihood of project success. Engineering students are increasingly participating in cross-cultural design projects; however, few studies have described what processes students use when identifying and evaluating needs in cross-cultural settings. This study followed an undergraduate student team as they conducted a needs assessment in a rural South American community. From this experience, participants developed conceptions of best practices for identifying their own subjectivity, soliciting many stakeholder perspectives, and engaging their partner community. However, participants also struggled to employ a variety of data collection methods strategically and analyze their data effectively. To address these challenges, engineering students require pedagogical support in specifying goals and collecting and analyzing qualitative data.

Keywords: needs assessment; cross-cultural design; design education; case study; co-curricular projects

1. Introduction

Identifying and evaluating stakeholder "needs" – the measurable gaps between stakeholders' present conditions and a hypothetical set of preferable conditions [1–6] – is an important aspect of design projects [7–10]. Previous studies have shown that project failures, especially in cross-cultural design contexts, can often be traced back to poor understanding of stakeholder needs [10–14]. Challenges in identifying and evaluating stakeholder needs are heightened in cross-cultural contexts due to significant cultural differences between designers and stakeholders [9–12]. As such, designers who will be working in cross-cultural contexts need to develop competencies for stakeholder and community engagement and combine these competencies with previous technical knowledge as part of a rigorous process for needs identification and evaluation [11, 12, 15, 16].

Needs assessments – rigorous processes for needs identification and evaluation – are described in disciplines as diverse as general organizational planning [1], international development [2], medical device design [3], and social work [4]. While specific methodology changes slightly with context, all of these fields emphasize that needs assessments are open-ended, reflexive, and iterative so that needs assessment teams can fully explore stakeholder perspectives on needs and recognize how their own individual subjectivity influences their perceptions of these needs [1–6]. The goal of conducting needs assessments is to help ensure that any implemented solution addresses real stakeholder needs.

Undergraduate engineering students are increasingly participating in cross-cultural, community-oriented design projects involving the identification and evaluation of community needs – in other words, projects where needs assessments should be conducted. Many of these projects are initiated and led by the students themselves (e.g., [17–20]). However, engineering students often have limited prior needs assessment skills because pedagogy related to these skills is not part of standard undergraduate engineering curricula [15, 21–23]. For example, few engineering programs offer instruction on how to engage with stakeholders within communities, which is a central activity in needs assessments [21, 23, 24], and the literature documents that students often struggle with community engagement aspects of their cross-cultural projects [12, 13, 17, 25]. While some programs have developed student training opportunities for community engagement (e.g., [16, 26]), detailed accounts of engineering students employing these engagement skills in practice are rare. Thus, we studied an undergraduate student team engaged in a cross-cultural design project to understand what these engineering students knew about needs assessments, how they conducted a needs assessment as part of a cross-cultural design project, and their learning gains from their needs assessment experience.

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2. Research Background

2.1 Needs Assessment as a Rigorous Needs Identification and Evaluation Process

A "needs assessment" is "a systematic set of procedures undertaken for the purpose of setting priorities and making decisions about program or organizational improvement and allocation of resources. The priorities are based on identified needs [1, p. 4]." Methodologies resembling needs assessments have been employed in cross-cultural design projects in the past (e.g., [8–10]); however, descriptions of these methodologies have focused mainly on practices for needs identification rather than comprehensive assessment of and decision-making about needs. Needs assessments represent a process that designers in cross-cultural contexts could use not only to identify stakeholder needs but also to evaluate these needs and decide which needs the design team could most realistically address [15].

Needs assessments involve three main phases of activity: pre-assessment, assessment, and post-assessment [1, 2] (summarized in Fig. 1). During the pre-assessment phase, a diverse team should be assembled. This team should work together to clarify goals for the needs assessment, conduct contextual research on the community and relevant prior work, and identify key stakeholders that the team should interact with during the assessment [1–6, 27]. Several frameworks exist to help designers plan and organize this contextual research (e.g., [12, 24, 28]). During the pre-assessment phase, the team should also develop their data collection tools, including interview protocols and observation frameworks, and identify potential screening criteria for future needs filtering [1–6, 27].

Once pre-assessment activities have been completed, the team begins the assessment. During the assessment phase, the team should employ a range of qualitative and quantitative research methods, such as interviews, observations, surveys, and focus groups, to collect data from stakeholders that might be used to identify needs [1–6, 27]. While the team collects data, they should also perform preliminary analyses to verify the quality of the data being collected and identify initial needs that may drive iterations on the team's data collection approach [1–3, 6]. The team may also use these data to iterate on their initial screening criteria [2, 3]. The assessment phase ends after the team has performed rigorous qualitative and/or quantitative analyses on the full data set to identify recurring trends and/or themes that correspond to community needs [1–6, 27].

Finally, during the post-assessment phase, the team should continue to refine their definitions of identified needs to ensure that addressing these needs will have the intended outcomes for stakeholders [1–3]. The team should then filter these needs based upon a finalized set of screening criteria to identify which needs the team and/or their partner community or organization could most feasibly address [1–3, 5, 6]. Based on this final list of prioritized needs, the team should develop a plan of action and report this plan to their partner [1, 2, 4–6, 27]. By the end of the post-assessment phase, the team should be able to justify committing substantial resources to future action through comprehensive descriptions of community or organizational needs [1–6, 27, 29–31].

2.2 Needs Assessment Best Practices

Several needs assessment best practices (summarized in Table 1) have been suggested across disciplines.

Needs assessment teams should be mindful of their own subjectivity as practitioners to avoid biasing their needs assessment process [2–6, 27, 29]. Reflexivity is necessary because a team's perspective on "needs" will influence their approach to data collection and analysis [2, 4–6, 30]. For example, teams that define needs only as deficits might overlook the unique strengths of the partner com-

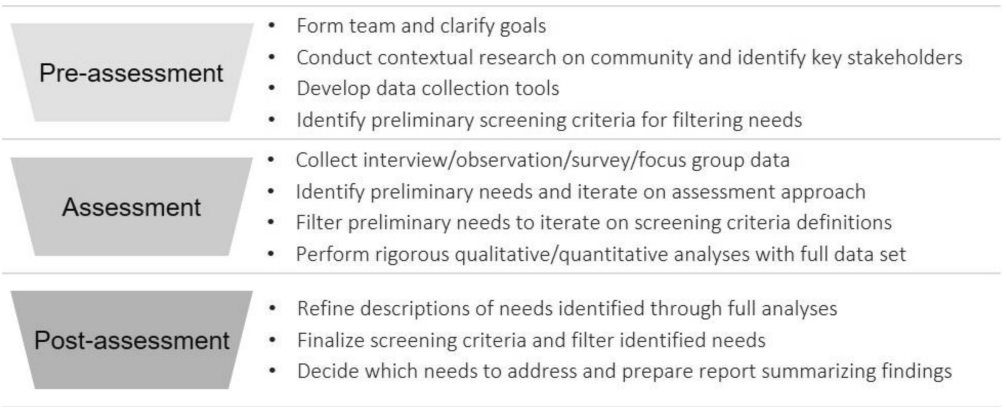

Fig. 1. Overview of needs assessment process (adapted from content in [1, 2]).

Table 1. Needs assessment best practices identified from the needs assessment literature

Best practices	References	Definition
Identify how own subjectivity influences process	[2–6, 27, 29]	Identify how the team's collective expertise and previous experiences may influence the team's perspective on needs and approach to conducting a needs assessment
Collect many different types of data	[1–6, 29]	Collect and compare conclusions across many different types of data, such as interviews, observations, surveys, and focus groups
Select data collection methods based on specific criteria	[1, 2, 4, 5, 29]	Select data collection methods that are well-suited to the goals of the needs assessment and appropriate for stakeholders
Interact with a wide variety of stakeholders	[1–6, 27, 29]	Solicit input from many different stakeholder groups in the community or organization
Develop rigorous metrics to evaluate and prioritize needs	[1–6]	Develop consistent standards of comparison to evaluate the reliability and relevancy of identified needs and determine which needs to address first
Engage community or organization as equal partners	[2, 3, 27, 29, 31]	Engage the partner community or organization as equal participants in the needs assessment process to build partner capabilities and support the partner in addressing identified needs

munity or organization that could be leveraged to address identified needs [5, 27, 29–31]. In a cross-cultural context, a designer's outsider perspective may also bias their perception of the root political or economic conditions that give rise to stakeholder needs [11, 16, 25].

Needs assessment teams should collect many different types of data [1–6, 29]. This recommendation arises because each data source has inherent limitations; for instance, stakeholders may have trouble verbalizing implicit knowledge during interviews [32, 33]. In the qualitative and mixed methods literature, this best practice is often referred to as "triangulation" [34–38]. By comparing the differences in conclusions that might be drawn from different data sources or data collection approaches, a needs assessment team might address potential validity threats related to their interpretations of community needs.

Needs assessment teams should select their data collection methods based upon specific criteria related to the goals of the needs assessment and qualities of community or organization stakeholders [1, 2, 4, 5, 29]. Teams should be able to justify that the data collection methods they select are well suited for eliciting useful information related to the assessment because these methods determine the content, reliability and validity of the information that the needs assessment team may uncover [35–39]. For example, designers in cross-cultural design contexts might chose to employ visual tools and representations (e.g., [7, 40, 41]) as part of their data collection approach due to the difficulties associated with communicating verbally across language barriers.

Needs assessment teams should collect data from a wide variety of stakeholders [1–6, 29]. This breadth serves as another form of triangulation that can help teams develop valid descriptions of community needs [34–38]. Furthermore, teams should interact with a wide variety of stakeholders because each stakeholder group in a community or organization may experience the same need differently; while addressing a given need may have a positive impact on one group, it could also have a negative effect on another group [1–6, 29]. Interacting with a wide variety of stakeholders is thus necessary to understand the benefits and consequences of potential action and to identify the full range of relevant stakeholders who might be affected.

Needs assessment teams should develop valid and consistent metrics to evaluate and prioritize identified needs [1–6, 29]. These metrics can help ensure that needs assessment teams are making well-founded judgments about which needs should be addressed. Needs filtering metrics should take into account the potential impacts of addressing a given need, the needs assessment team or partners' capabilities to address the need, and the team or partners' motivations to address the need [1–3, 5]. Evaluating needs according to these metrics can help the team and their partner community or organization determine how they can best allocate available resources in order to achieve tangible positive outcomes with the partner.

Finally, needs assessment teams should engage the partner community or organization as equal participants in the needs assessment process to build partner capabilities and support the partner in both addressing current needs and identifying future needs [3, 27, 29, 31]. The needs assessment team should be transparent with their partner community or organization about

their needs assessment process and the data they are collecting, check with partners to validate initial conclusions, and involve partners in making decisions based on assessment findings. Participatory data collection techniques (e.g., [41–44]) may also be effective for engaging the partner community or organization and building partner capabilities.

2.3 Needs Assessments in the Context of Cross-Cultural Student Projects

Undergraduate engineering students are increasingly participating in, and in many cases leading (e.g., [17–20]), cross-cultural, community-oriented design projects involving the identification of needs and the subsequent development of solutions to address a subset of the identified needs. These projects take place in both curricular and co-curricular settings, such as design courses with an international development focus or international service-learning projects. Previous studies suggest that participating in cross-cultural design projects can help engineering students develop skills for cross-disciplinary communication and teamwork [15, 45–47], cross-cultural communication [15, 17, 18, 47, 48], adaptive problem-solving [15, 45, 47–49], design ethnography [15, 48], reflection [17, 48, 50], and management of ambiguity due to limited information [50, 51]. Each of these skills may be helpful for identifying and evaluating needs in cross-cultural settings.

However, while cross-cultural design experiences benefit engineering students, there are several examples of projects failing to produce successful design outcomes for the partner community. In many cases, these project failures are due to students lacking an adequate understanding of community needs and the broader context of their projects [12, 13, 17, 52]. Students may frequently struggle to understand community needs because instruction relating to needs assessments and community engagement is not part of standard undergraduate engineering curricula [15, 21–24]; students may consequently encounter difficulties when trying to identify and evaluate needs in their partner community [12, 17, 25]. Furthermore, the short time frame of many projects involving students (e.g., the projects described in Harshfield et al. [17] and Klopfenstein et al. [53], both of which implemented solutions roughly a year after first establishing their respective community partnerships) may hinder the ability of students to engage deeply enough in needs assessment to develop and implement robust solutions.

The majority of studies involving engineering students in cross-cultural settings have described situations where students iterated on or generated solutions for needs that had already been identified. While a few studies have discussed situations where students contributed to the initial identification of needs (e.g., [15, 54–56]), these accounts focused on the community need that was ultimately identified rather than the specific competencies students employed to identify needs or choose a project direction.

3. Methods

3.1 Research Questions

This study sought to understand what an undergraduate engineering student team knew about conducting needs assessments and how their knowledge changed as a function of conducting a needs assessment. We also wanted to explore the challenges that engineering students may encounter as part of conducting needs assessments. Our study was thus guided by the following research questions:

1. What do engineering students think are best practices for conducting needs assessments?
2. How do student perspectives on these best practices change as a result of conducting a needs assessment?
3. What challenges do engineering students encounter when conducting needs assessments? How do these challenges affect student processes?

3.2 Design Context

Data for this study were collected from a team of twelve students who conducted a needs assessment in a rural South American community (the ''partner community''). The needs assessment was sponsored by an undergraduate co-curricular organization that specialized in medical device design for low-resource settings. The organization had sponsored several needs assessments in the past and used the term ''needs assessment'' to describe these endeavors. This needs assessment was the organization's first in this specific partner community; the organization's goal was to establish local partnerships and identify needs that might form the basis for future co-curricular projects. This study focused primarily on the pre-assessment (7 weeks) and assessment (1 week) phases of the team's needs assessment.

As part of the team's pre-assessment phase, the team completed training related to conducting observations, conducting a needs assessment, and developing needs statements through the University of Michigan's Center for Socially Engaged Design (C-SED) [26]. C-SED offers a variety of training modules related to employing design ethnography methods such as interviews and observations, analyzing stakeholder data to develop needs statements and user requirements, and generating creative

solutions to design problems. These modules are completed individually and blend an online review of best practices with in person practice and coaching [57]. Each module includes prior knowledge reviews, content quizzes, practice application tasks, and reflections that in total typically take around five hours per person to complete. The three topics that participants covered were selected by the team's leadership as the highest priority topics based upon the activities that the team expected to perform while in the partner community. Content included in the needs assessment module drew heavily from the recommended practices described in Zenios et al. [3], Watkins et al. [2], and Royse et al. [4].

The team's assessment phase involved a one-week service-learning experience organized in collaboration with a local partner non-profit organization (the "partner organization"). While in the partner community, the team spent several hours each day conducting observations of community medical centers and interviewing local villagers. The team was aided by two individuals from the partner organization (hereafter referred to as "the guides"). One guide was from the community where the team was collecting data. The other guide was the same nationality as the team but had lived in the community for some time. While in the community, the team split into two main subgroups to interact with as many stakeholders as possible. The team then reconvened each night to discuss the data they had collected thus far, reflect on their experiences, and plan what data they wanted to collect during the next day.

3.3 Participants

Demographic information for the twelve members of the needs assessment team are shown in Table 2 (names are pseudonyms). Qualitative work often involves deep exploration of select samples or cases to facilitate identification of elements from participant experiences that may be transferable to similar contexts [37, 38]; the sample size of this study is in alignment with other similar qualitative longitudinal studies of student cross-cultural design experiences (e.g., [17, 47, 49, 51]). Participants generally had one to three semesters of curricular design experience, depending upon their year and program. Several participants also had six to eighteen months of co-curricular and/or internship design experience, particularly through the co-curricular organization that was sponsoring the needs assessment. None of the participants had conducted a needs assessment as part of their previous design experiences, although one of the two team leads, Alli, had previous experience employing design ethnographic methods such as interviews and observations to collect in-depth information from users.

3.4 Data Collection

Participants completed three semi-structured group and individual interviews with a member of the research team: a "beginning of pre-assessment phase" interview, an "end of pre-assessment phase" interview, and an "end of assessment phase" interview. The timeline for these three interviews is shown in Fig. 2. The "beginning of pre-assessment phase" interview occurred before the team had begun in-depth pre-assessment activities and training and explored participants' perceptions about conducting observations, conducting needs assessments, and developing needs statements based on their previous design experiences. The "end of pre-assessment phase" interview occurred immediately before the team disembarked to conduct assessment activities in their partner commu-

Table 2. Participant demographics

Pseudonym	Year	Sex	Race/Ethnicity	Primary Major	Secondary Major/Minor
John	Freshman	M	White	Public Health	
Emma (Lead)	Master's	F	White	Biomedical Engineering	
Isabelle	Sophomore	F	Asian	Chemical Engineering	
Sophie	Freshman	F	Asian	Biomedical Engineering	
Jill	Sophomore	F	White	Industrial Engineering	International Minor for Engineering
Stephanie	Junior	F	Asian & White	Biomedical Engineering	American Culture
Chloe	Freshman	F	White	Biomedical Engineering	
Maria	Freshman	F	Hispanic	Public Health	Spanish
Emily	Sophomore	F	Asian & White	Mechanical Engineering	Music
Melissa	Freshman	F	Asian	Biomedical Engineering	Creative Writing
Arya	Freshman	F	Asian	Electrical Engineering	Business
Alli (Lead)	Junior	F	White	Mechanical Engineering	Multidisciplinary Design

nity and focused on how participants might use what they had learned about observations, needs assessments, and needs statements when collecting and analyzing their data. The "end of assessment phase" interview occurred after the team returned from the partner community. During the end of assessment phase interview, participants were asked to describe lessons learned from the experience, how they had applied the best practices learned during their pre-assessment training, and challenges encountered when collecting data in the community. Beginning and end of pre-assessment phase interviews occurred in four groups of three team members so that participants could elaborate on each other's responses. The composition of these four groups was the same for both interviews. Participants completed end of assessment phase interviews individually to allow the researchers more space to explore individual experiences.

Interview protocols were developed for each interview following recommended protocol development practices [34–36]. Since each interview explored participant perspectives on conducting observations, conducting needs assessments, and developing needs statements, the interview protocols provided a structured way to explore each topic in depth. Sample questions from the needs assessments portion of each protocol are shown in Table 3; these questions provided a starting point that prompted in-depth stories and examples from participants. When developing the beginning of pre-assessment phase interview protocol, we iterated on our questions by piloting the protocol with other undergraduate students who had similar relevant experiences. While we did not pilot the end of pre-assessment phase and end of assessment phase protocols, we kept track of participant experiences during their pre-assessment and assessment activities to ensure that our questions remained relevant to these experiences. For instance, the end of assessment phase protocol originally followed the observations, then needs assessments, then needs statements structure of the earlier two protocols. However, given the team's extensive reliance on stakeholder interviews once in the community, this end of assessment phase protocol was changed to a general data collection, then needs assessments, then needs statements structure instead.

Recordings of participant interviews (11 hours of audio) were transcribed to facilitate data analysis.

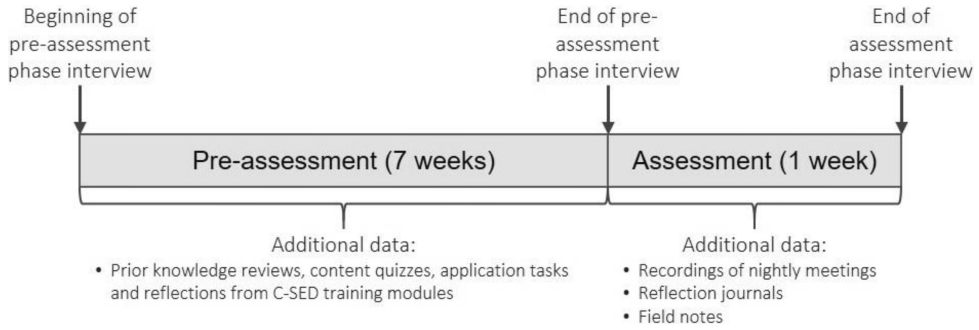

Fig. 2. Data collection timeline.

Table 3. Examples of questions pertaining to needs assessments asked during researcher interviews

	Questions
Beginning of pre-assessment phase interview	1. Why might designers or engineers conduct needs finding activities? 2. What prior experiences do each of you have with needs finding activities? 3. Based upon your prior experiences, how do you think you might conduct needs finding activities during your trip?
End of pre-assessment phase interview	1. Based upon your preparation, how do you think you might approach this needs assessment? 2. In addition to what we have discussed with observations, what do you think you might want to do to help the experience go well? 3. What best practices do you think the [modules] were emphasizing most relating to needs assessments? 4. Beyond those discussed regarding observations, what challenges do you anticipate encountering when conducting a needs assessment in [the community]?
End of assessment phase interview	1. Thinking across the experience as a whole, how do you think your needs assessment trip went? 2. In addition to data collection, what are some things that you or your team did that you think helped your needs assessment experience go well? 3. Which key takeaways about needs assessments from the [module] do you think you applied well? What about takeaways that were more difficult to apply? 4. What other challenges did you encounter when conducting needs assessment activities in the field? 5. What do you think you learned about conducting needs assessments from this experience?

In addition to the three interviews completed by each participant, we also collected other types of data, including submissions completed as part of the C-SED modules and individual assessment phase reflection journals where participants described how their activities aligned with needs assessment best practices. Each participant also submitted field notes from their assessment activities, and team leaders submitted recordings of the team's nightly assessment phase planning discussions. Team nightly discussions represented four hours of audio, while journal entries, field notes, and C-SED module submissions represented over one hundred pages of writing. We used these additional data to verify that participant interview responses accurately reflected participant perspectives on their pre-assessment and assessment activities [34–37]. Prior knowledge reviews from C-SED modules helped verify participant responses from beginning of pre-assessment phase interviews. Reflections from C-SED modules helped verify participant responses from end of pre-assessment phase interviews. The team's nightly discussions, individual reflection journal entries and field notes helped verify participant responses from end of assessment phase interviews.

3.5 Data Analysis

Two coders reviewed the transcripts of participant interviews several times to familiarize themselves with the data. These two coders then identified and described distinct participant responses to the needs assessment questions shown in Table 3. Responses were grouped thematically to develop an initial set of key themes that represented common team conceptions of needs assessment best practices as well as identified challenges [35, 38, 58]. Once this set of initial themes was defined, the two coders returned to the transcripts and identified additional responses that had been overlooked during the first round of analysis. The two coders discussed discrepancies in their respective interpretations of the themes that had been identified, iterated on the definitions of these themes, and settled on a final set of codes. NVivo 12, a qualitative analysis software, facilitated organization of our data during data analysis. The complete set of identified themes is discussed in Section 4.

4. Findings

Findings are presented below in five sub-sections. Section 4.1 outlines participant conceptions of best practices for conducting needs assessments at the beginning their pre-assessment phase. Sections 4.2 and 4.3 describe participant conceptions of best practices at the end of the team's pre-assessment and assessment phases, respectively. Section 4.4 summarizes challenges that the team anticipated for their assessment phase after completing their pre-assessment activities and training. Section 4.5 discusses challenges that the team encountered during their assessment phase.

4.1 Participant Conceptions of Needs Assessment Best Practices Reported at the beginning of the Team's Pre-Assessment Phase

Participant conceptions of needs assessment best practices reported during beginning of pre-assessment phase group interviews are listed in Table 4 in order of prevalence.

The two most common themes – *Keep an open mind* and *Follow up with stakeholders* – summarize the team's collective perspective on needs assessment best practices at the start of their pre-assessment phase. In the case of *Keep an open mind*, participants discussed the mindsets they would adopt to avoid biasing their perception of needs:

> "Just keep an open mind about needs. Even if something seems like it's fine at face value, there still might be a need there, but . . . don't be trying too hard to make mountains out of molehills." (Melissa)

Melissa felt that designers navigate two different challenges when perceiving needs. On one hand, designers might see situations that appear satisfactory but would reveal deeper issues with further probing. On the other hand, designers might see situations that initially seem problematic but are not substantial issues for stakeholders. *Keeping an open mind* can help designers avoid letting their assumptions cloud their perception of community needs.

All four participant groups also discussed the need to *Follow up with stakeholders* to check the validity of the conclusions they were drawing from their data, for example:

> "We're working with a non-profit when we go there, so those are people that are familiar with the environment. Just observing probably wouldn't be enough. Like also talking and observing something and being like, 'hey, I'm noticing this, is this something that's always like this, like is it a problem for people?' Getting some sort of perspective to your observations because as a person who doesn't know much about the environment, it's really useful to have that sort of input outside of just what you see." (Emily)

Emily stressed that observational data alone would likely be insufficient and that designers should compare their initial conclusions about potential needs to community perspectives on those needs. Her rationale was that her team did not have much contextual knowledge about the community, so stakeholder perspectives would likely be needed to provide greater context into the needs that the

Table 4. Participant conceptions of needs assessment best practices reported during beginning of pre-assessment phase group interviews

Conceptions of needs assessment best practices	# of groups (of 4)	Definition	Example
Keep an open mind	4	Keep an open mind and avoid making assumptions about community needs	"Maybe just keep an open mind about needs. Even if something seems like it's fine at face value, there still might be a need there, but. . . don't be trying too hard to make mountains out of molehills." (Melissa)
Follow up with stakeholders	4	Follow up with stakeholders to check the validity of preliminary conclusions	"Just observing probably wouldn't be enough. Like also talking and observing something and being like, 'hey, I'm noticing this, is this something that's always like this, like is it a problem for people?' Getting some sort of perspective to your observations . . ." (Emily)
Identify potential needs in advance	2	Have an idea in advance of what types of needs may exist in the community	"In being prepared, I think we need to arrive there with some idea of what we're looking for, not just like, 'Oh, what's going on?'. . . Kind of milling with the scope of things that we can bring back to [our organization]" (Stephanie + Jill)
Don't cross boundaries	1	Don't cross boundaries to avoid offending stakeholders	"I feel like it's going to be more observation based than interaction based because, not crossing boundaries . . . Making sure we don't offend the people we're observing because it is a medical clinic . . . People are coming in here when they're vulnerable." (Maria + Emily)
Let stakeholders guide conversation	1	Give stakeholders space to talk about the topics that are most important to them to help uncover root needs	"I'd say it's important to keep questions really broad and let the person you're talking to steer the conversation the way that's most important to them, because that's how you'll get at the root need that they have." (Alli)
Conduct research to understand culture	1	Conduct prior research to learn about the culture of the community	". . . Read up as much as [you] can and gain as much information as [you] can before [you] go somewhere totally new. Because once again it goes back to the whole idea, you should be well aware of what their environment and their culture is like." (Chloe)
Communicate within team	1	Communicate within the team to make sure all team members have necessary information	"Prepare and communicate with the other [planning] sub teams as well, so we have all the information that we need." (Sophie)
Visit other places and compare data	1	Collect data from different locations to compare with data collected during the needs assessment	"I think something we could do . . . just to have a comparison is to visit other places . . . Maybe not in [the same country], but once we're done there, go somewhere else and see what [others] are doing compared to what [the community] were doing." (Chloe)

team was identifying. While Emily singled out the team's non-profit partner organization as a key group to follow up with, other participants also discussed following up with clinicians in the community health centers or other members of the community.

While discussing these two specific best practices, participants often referred to their previous education and experiences for justifying their suggestions. For example, many of the participants described being exposed to case studies of failed design projects through their curricular and co-curricular experiences:

> "I feel like there are many instances of engineers . . . trying to define for others what they think the needs are. If any of you guys were at the design showcase, the one story about the filter straw? They saw a need for filtered water, and because they didn't do a needs assessment they made a filter straw, which was very culturally insensitive because they were imagining [their users] would take the straw and drink from the dirty river and it was a really bad needs assessment. I mean, there may have been an actual need for water filtration but that wasn't the correct way to go about it. I think it's important to hear from the people that you're actually trying to assist, hear what they actually want assistance on . . ." (John)

By referring to the example of the filter straw, John highlighted a concrete situation where designers made inaccurate assumptions about stakeholder needs because they did not conduct an effective needs assessment. While the base need (access to clean water) was legitimate, the design team did not adequately explore all relevant factors when defining this need and their solution failed as a result. For John, the main takeaway of this example was that the design team should have engaged more with their stakeholders. In other words, designers should *Keep an open mind* when conducting needs assessments and can do so by *Following up with stakeholders* to verify conclusions.

4.2 Participant Conceptions of Needs Assessment Best Practices Reported at the end of the Team's Pre-Assessment Phase

Participant conceptions of needs assessment best practices reported during end of pre-assessment phase group interviews are listed in Table 5 in order of prevalence. Compared to the beginning of pre-assessment phase interviews, there were no end of pre-assessment phase conceptions that appeared consistently across all four participant groups. This relative lack of consistency may have been because each participant focused on different key takeaways while completing the C-SED needs assessment module (hereafter, "the C-SED module").

One of the more common themes – *Justify identified needs* – focused on how designers should consider community context when describing needs and justify that descriptions of needs are supported by data. As Emily explained:

> "Before I [thought] you're just going to be looking at something and say, 'Okay, what does this person need right now?' It's way more than that. There's so much depth to the number of people that are involved . . . and how prominent that certain problem is. I think it'll help me to think beyond just what you see. What you see isn't always the need, there might be something . . . deeper that you may have to find." (Emily)

Initially, Emily thought that identifying needs would be as simple as observing a stakeholder in a certain situation and identifying potential deficiencies. However, after completing the C-SED module, she realized that needs are complicated and that everyone experiences needs differently: what may be a problem for one stakeholder may not be a problem for another. Emily also emphasized that there are different types of needs. While designers might identify surface needs based on observations, many times there are also deeper needs that designers may need to uncover. Several other participants also referred to different ways of categorizing needs, such as needs that could be addressed with available resources compared to needs that might require radical innovations.

Participants again emphasized the importance of

Table 5. Participant conceptions of needs assessment best practices reported during end of pre-assessment phase group interviews

Conceptions of needs assessment best practices	# of groups (of 4)	Definition	Example
Justify identified needs	3	Justify descriptions of identified needs based on available data	"There's so much depth to the number of people that are involved... and how prominent that certain problem is . . . What you see isn't always the need, there might be something . . . deeper that you may have to find." (Emily)
Follow up with stakeholders	3	Follow up with stakeholders to verify that identified needs correspond to true community needs	". . . any way that we can try to get from them what they think is important . . . what they think could change would be really helpful. . . because they are the ones dealing with this clinic every day. We're only there for a week. We can't see everything." (Jill)
Conduct research to help build rapport	2	Researching the culture of the community in advance will help with building rapport	"Just making the small efforts to understand or know something about their culture beforehand right when you get there, it really shows that you've made an effort and that you're here to talk to them." (Isabelle)
Have a plan	2	Develop a detailed plan in advance for conducting a needs assessment	"I think that our needs assessment is going to be much more organized and structured. I think we're going to definitely incorporate some of the frameworks that we. . . learned from [the C-SED modules]." (Maria)
Identify questions to ask	1	Think of potential questions to ask stakeholders before entering the community	"I don't think having really strict interview protocols is important, but maybe just having an idea of the types of questions you'd want to ask so that you have more of a. . . reading to start with. . . and then conversations kind of go where they go." (Alli)
Be solution neutral	1	Focus on needs rather than potential solutions	"Don't focus on the solution. . .You have to focus on the actual need and where the gap in productivity would be." (Jill)
Avoid offending stakeholders	1	Avoid unintentionally offending stakeholders while collecting data	". . . We're there to do design observations and a needs assessment, but don't get so caught up in that that we also offend the clinicians by getting in their way. 'Cause we're there for one task, but they're also still trying to do their jobs . . ." (John)
Identify appropriate scope of needs	1	Identify the scope of needs that the team can address	"They also talked about the scope and how much. . . we can actually handle, so that would help with building things." (Sophie)

Following up with stakeholders and reiterated many of the same points made in the beginning of pre-assessment phase interviews, including that this practice can help ensure that needs identified by the team corresponded to true needs in the community. During end of pre-assessment phase interviews, participants also emphasized that this best practice was especially relevant in their case since they would be in the community collecting data for a relatively short amount of time. As Jill described:

> "I don't think we'll be able to have formal interviews with [our stakeholders], but any way that we can try to get from them what they think is important . . . what they think could change would be really helpful towards the needs assessment because they are the ones dealing with this clinic every day. We're only there for a week. We can't see everything." (Jill)

As in her beginning of pre-assessment phase interview, Jill emphasized that soliciting stakeholder perspectives on needs would significantly benefit the team's needs assessment process. However, in this case, Jill also explicitly referred to how the time constraints of the team's assessment phase were going to limit the data that the team could collect. Jill thus felt that stakeholders could provide valuable input in describing aspects of community needs that the team would not have time to observe directly. Several participants also discussed the need to plan out these follow up activities as part of the team's nightly discussions.

4.3 Participant Conceptions of Needs Assessment Best Practices Reported at the end of the Team's Assessment Phase

Participant conceptions of needs assessment best practices reported during end of assessment phase individual interviews are listed in Table 6 in order of prevalence.

The needs assessment best practice most commonly cited by participants was *Account for diverse perspectives*. Participants discovered during their assessment activities that their stakeholders all had individual perspectives on potential community needs; the team thus felt that they needed to explore these different perspectives in order to understand which needs in the community were most relevant. As described by John:

> "Going to all the different communities was great because we got to hear different perspectives, which also helped us get a more holistic view, because I know

Table 6. Participant conceptions of needs assessment best practices reported during end of assessment phase individual interviews#

Conceptions of needs assessment best practices	# of students (of 12)	Definition	Example
Account for diverse perspectives	12	Account for diverse stakeholder perspectives to understand community needs in greater depth	"Going to all the different communities was great because we got to hear different perspectives, which also helped us get a more holistic view." (John)
Leverage local connections	10	Leverage local connections to build rapport in the community	"If you are doing a needs assessment in a more remote, foreign, completely different cultural area, it's important to use something that's already there to implant yourself." (Stephanie)
Compare data across team	9	Share observations and interpretations across team members to compare different perspectives	"Even though we often were together as a group, how we perceived that experience, and what observations we were making, were very different amongst us. I think having the opportunity to share. . . and bounce ideas off each other was extremely helpful." (Maria)
Avoid biasing data collection	5	Avoid embedding opinions or solutions when collecting data	"I think being objective... Making sure I'm not putting my opinions in what we're doing. Then, also not trying to target anything towards solutions." (Jill)
Keep an open mind about needs	5	Keep an open mind about potential community needs	"If you go in with a narrow perspective . . . you might be missing a lot of things . . . We knew we wanted to do something health care related, but then there's education and government and . . . all of those things are related, so just don't go in with a narrow mindset." (Emily)
Adopt flexible data collection approach	3	Adapt data collection approach to changing circumstances during stakeholder interactions	"When the conversation would go off, I could still come up with new things I wanted to learn about. . . because there was so much information that we needed to know. I felt that I wasn't stuck on any one thing." (Alli)
Take good notes	3	Record notes in enough detail to justify the needs identified by the team	"Taking good notes was a big thing. If you don't have good observations, you can't do good needs assessment and you can't do good need iteration." (Emma)

> for example, one woman we talked to said the greatest problem was their ineffective community leaders. But then we heard from our [guide] that was likely due to the fact that she was [a religious minority]. Her religion distanced her from the rest of the community, so it was like her personal factors. In speaking with other community members, we found that certainly was not the most pertinent issue. It was very beneficial, though, that we got a wide range of perspectives." (John)

As John discussed, the team encountered divergent opinions from stakeholders relating to potential community needs, in this case the ineffectiveness of community leaders. The team found that one woman, who happened to be a religious minority, possessed a substantially different view on this need than the other members of the community. By interacting with a variety of different stakeholders, the team realized that this need, while important to this individual woman, was not a priority for the majority of community members.

Participants also felt that working closely with key stakeholders, such as their guides, helped the team conduct their needs assessment. Participants frequently cited *Leveraging local connections* as an important practice to build initial rapport with stakeholders. As Stephanie described:

> "We would not have been able to do a lot of those things if we didn't have access to our tour guides. It would've been so much harder to just get yourself into a community. If you are doing a needs assessment in a more remote, foreign, completely different cultural area, it's important to use something that's already there to implant yourself. . . if we had just showed up and knocked on these people's doors, and were like, 'Hey, I wanna ask you a few questions,' they probably would've said no, and then there would've been a huge language barrier . . . I guess, being really prepared for that kind of stuff is just the most important." (Stephanie)

Stephanie recognized that the team's guides played a key role in helping the team interact with the community. The team's guides lived in the community and were well known to many of the individuals with whom the team interacted; they thus proved to be a valuable resource for making contacts and building relationships. The guides further facilitated these interactions by acting as translators for the team. By *Leveraging local connections*, participants felt that they were able to build rapport and communicate with their stakeholders more successfully than they might have been able to otherwise.

Nine of the twelve participants highlighted how being part of a cross-disciplinary team with many diverse perspectives benefitted the team's assessment activities. By *Comparing data across the team*, team members felt that they were better able to understand how their own individual perspectives influenced how they perceived their data. The following excerpt provides a typical account:

> "I would definitely say the daily debrief sessions were a huge help. Without that opportunity to hear what other people were thinking and get other individual takes on the same situation, I think we would have missed out on a lot of observations and potential needs statements. Even though we often were together as a group, how we perceived that experience and what observations we were making was very different . . . I think having the opportunity to share with other individuals and bounce ideas off each other was extremely helpful." (Maria)

Maria felt that without the diversity of perspectives among team members, the team would likely have missed out on several surprising insights while in the community collecting data. Even though team members often conducted observations and interviews in groups together in the same location, Maria highlighted how team member perceptions of those experiences were very different. Participants claimed that comparing different perspectives and ideas thus helped their team identify their individual biases, and that discussing these biases led the team to identify new needs from their data that they might have missed otherwise.

4.4 Needs Assessment Challenges Described at the end of the Team's Pre-Assessment Phase

The needs assessment challenges described by participants during end of pre-assessment phase group interviews are listed in Table 7 in order of prevalence. These challenges related to difficulties that participants expected to encounter during their assessment phase activities. Four themes, *Overcoming team biases*, *Optimizing short time in community*, *Managing extensive data*, and *Navigating language barriers*, described anticipated challenges directly. Two themes, *Practicing assessment skills* and *Finding contextual information*, described challenges encountered during pre-assessment activities that participants felt might impact their assessment phase.

The most common anticipated challenge described by participants was *Overcoming team biases* that might influence how the team perceived community needs during data collection. As one participant described:

> "We all have higher education. We're all from [Midwestern University]. We all have specific subjectivity as a group, so I think avoiding that is something that's gonna be a hard challenge for us all." (Emma)

Emma highlighted participants' higher education and shared university context as factors that might contribute to collective biases that the team may struggle to identify and overcome. Other team members also emphasized that their lack of familiarity with the community's health care system might bias their perception of potential needs and that as engineers they had a bias towards embedding solutions in identified needs.

Table 7. Challenges described during end of pre-assessment phase group interviews

Needs assessment challenges anticipated	# of groups (of 4)	Definition	Example
Overcoming team biases	3	The team has collective biases that may influence the objectivity of the needs assessment	"We all have higher education. We're all from [Midwestern University]. We all have specific subjectivity as a group, so I think avoiding that is something that's gonna be a hard challenge for us all." (Emma)
Practicing assessment skills	2	The team had limited opportunities to practice conducting a needs assessment	"Practice is always helpful. We haven't done a ton of that other than the application [task]." (Jill)
Finding contextual information	2	The team struggled to find additional information about the specific community	"We don't exactly know what we're going to be doing today. It's hard to prepare . . . since we don't have that information [on the clinics] available to us. We can really only do research about the culture. . ." (Jill)
Optimizing short time in community	2	The team will have a very short amount of time in the community to collect data	"I think that the time constraint that we have might also make it kind of difficult. We are only there for a week, but that week is . . . There's a significant chunk taken out of that week due to travel." (Stephanie)
Managing extensive data	1	The team may struggle to manage the substantial quantity of data that they plan to collect	"Just finding an effective way to go through the copious amount of notes that we'll have without losing objectivity or without making [the data] less effective . . . finding a way to make it more manageable." (John)
Navigating language barriers	1	Due to the language barrier, the team may struggle to understand the nuances of stakeholder responses	"I think the language barrier is gonna be something because even though I know a little bit of Spanish and all of that I don't think I know enough to pick up on the nuances of their language . . ." (Melissa)

4.5 Needs Assessment Challenges Described at the end of the Team's Assessment Phase

The needs assessment challenges reported by participants at the end of their assessment phase are listed in Table 8 in order of prevalence. Four challenges, *Understanding the context, Optimizing short time in community, Executing recommended practices from training* and *Navigating language and cultural barriers*, were anticipated by participants but had implications that only became clear for participants during their assessment phase. The other four challenges, *Accessing stakeholders*, *Recording data during fast-paced interactions*, *Evaluating needs*, and *Identifying appropriate needs*, were discovered by participants while completing their assessment activities.

Three key challenges were reported most often across participants: *Understanding the context*, *Optimizing short time in community*, and *Accessing stakeholders*.

Eleven out of twelve participants discussed challenges related to *Understanding the context* of the team's partner community. Without prior knowledge about this community, participants reported that the team struggled to plan out their data collection experiences and identify potential need areas to explore in advance. As a result, participants felt that their team's needs assessment approach was disorganized and that they could not verify the information on the community that they received from their guides:

> "I felt like if we had been given slightly more information about what part of the river we were going to or had done more general research, we would've been able to target our questions more from the beginning rather than having to gather so much general information that we probably could've [learned] before." (Jill)

Jill felt that the team did not have enough information in advance to identify targeted questions to ask stakeholders. From her perspective, the team spent too much time collecting general information that could have been researched before entering the community. Several participants acknowledged that this *Understanding the context* challenge was a result of their own negligence and impacted the team's ability to plan out their observation experiences in advance as well. However, many participants also discussed that even when they tried to research the community, they had struggled to find relevant information. This challenge thus represented an outcome of the *Finding contextual information* challenge described by some participants during end of pre-assessment phase interviews.

Ten out of twelve participants cited *Optimizing short time in community* as a key challenge. These participants pointed out that they did not have time

Table 8. Challenges described during end of assessment phase individual interviews

Needs assessment challenges encountered	# of students (of 12)	Definition	Example
Understanding the context	11	The team struggled to optimize data collection activities based on limited understanding of the community context	"I felt like if we had been given slightly more information about what part of the river we were going to or had done more general research, we would've been able to target our questions more from the beginning . . ." (Jill)
Optimizing short time in community	10	The team had limited time in the community, which limited the amount of information they could collect	". . . at the end of the week, I noticed that we had our needs statements, but even then from there I knew we had very little information." (John)
Accessing stakeholders	7	The team did not have access to several relevant stakeholder groups	"We talked to a lot of people in the community and maybe one person who's actually in the community government, and we didn't get anyone who was higher up in that spectrum, so everything was from a very one class point of view." (Emily)
Recording data during fast-paced interactions	4	The pace of stakeholder interactions made it difficult for the team to collect quality data	"You're trying to write things down and there's something else happening over there because someone's asking another question . . . I think out in the field, it moves a lot faster than I was expecting. It's a lot harder to do everything and to get it all done well." (Alli)
Evaluating needs	3	The team struggled to evaluate the relevance of identified needs in the community	"I think determining if it's a need or not was very hard . . . You see someone in such poverty . . . Remembering that maybe it is not a need necessarily for them, but something that you think they need because it's not like your life . . ." (Emma)
Executing recommended practices from training	2	The team struggled to translate lessons from their pre-assessment training to real-world practice	"I think there's a formal procedure kind of like the needs assessment [module], but obviously it's kind of hard to do that in real life. Nothing ever works out as black and white as you're expecting it to . . ." (Emily)
Identifying appropriate needs	2	The team struggled to identify needs of the right scope that they could realistically address	"We made sure that our scope wasn't so narrow or too broad, but. . . it was also difficult to know what we can do because a lot of the problems were about what the government does and there were many things that we can't fix as a [student] group." (Sophie)
Navigating language and cultural barriers	1	Language and cultural barriers impacted the team's contextual understanding during stakeholder interactions	"We were concerned that they sent their patients away because they wanted to help us, and we obviously didn't want that to be happening. . . That was difficult, partially a translation barrier and partially a cultural barrier. We just didn't understand what was happening." (Jill)

to observe the same location across multiple days or follow up with specific individuals to collect more data. As such, participants felt that they had some indication of issues in the community but were still forced to make extrapolations about specific needs based on limited data. As one participant explained:

> "Even before we went, there was talk about how a needs assessment usually takes a very long time. Something I noticed during the modules was how it typically would take us months and years . . . because at the end of the week, I noticed that we had our needs statements, but even then from there I knew we had very little information. There was still a lot of leaping that we had to do." (John)

As John discussed, needs assessments often take months or years, compared to the single week that the team was in the community. Many participants felt that their approach was as effective as it could have been given the amount of time available; even so, John acknowledged that the team had limited information and had to rely on assumptions and extrapolations when developing needs statements. Similar to the *Understanding the context* challenge, *Optimizing short time in community* had been anticipated as a challenge by some participants during end of pre-assessment phase interviews. However, participants only elaborated on the implications of the *Optimizing short time in community* challenge for their needs assessment process after completing their data collection activities.

Seven participants described a third challenge: *Accessing stakeholders*. In addition to having limited time in the community, the team also had little control over with whom they could interact. As such, the team was not able to collect data from a fully representative sample of community stakeholder perspectives:

> "We didn't always feel like we were getting a complete picture of everything, 'cause we talked to a lot of members of the community, and we didn't really

> get . . . For example with the government, we talked to a lot of people in the community and maybe one person who's actually in the community government, and we didn't get anyone who was higher up in that spectrum, so everything was from a very one class point of view. There might be problems that they think are there, that there's a reason that they can't be solved. Or they are being worked on but they just don't really know." (Emily)

While participants wanted to collect data from a diverse group of stakeholders to develop comprehensive understandings of potential community needs, they also struggled to account for all these perspectives in practice. For example, Emily highlighted that while the team was exploring community needs related to the local government, they were largely unable to collect information related to the government's perspective on these needs. Emily felt that the team thus struggled to verify the validity of the government-related needs that they were identifying. This challenge was not anticipated by participants during end of pre-assessment phase interviews.

5. Discussion

5.1 Participant Conceptions Of Needs Assessment Best Practices Compared to Best Practices in the Literature

The research findings demonstrated that our participants already had some conceptions of needs assessment best practices before beginning pre-assessment activities. Participants developed these conceptions further and identified new conceptions as a result of their pre-assessment and assessment activities. Comparing participant conceptions at each stage can help us track the development of participant conceptions over time, as well as identify how the challenges encountered by participants impacted this development. The development of participant conceptions over time is summarized in Table 9, as well as the challenges described by participants at end of each phase.

Comparing participant conceptions of best practices to needs assessment best practices sourced from literature (Table 1) can also help clarify which literature best practices participants learned during their pre-assessment and assessment phases and which literature best practices were more challenging to learn. In particular, participants developed conceptions related to identifying how their own subjectivity influenced their process, interacting with a wide variety of stakeholders, and engaging the community as equal partners. However, participants struggled to develop conceptions related to collecting many different types of data, selecting data collection methods based on specific criteria, and developing rigorous metrics to evaluate needs.

Identify how own subjectivity influences process [2–6, 27, 29]**.** Participants described several concep-

Table 9. Development of participant conceptions of needs assessment best practices over time and challenges described at the end of each phase

Proportion of team	Beginning of pre-assessment phase conceptions of best practices	End of pre-assessment phase conceptions of best practices	Challenges described at end of pre-assessment phase	End of assessment phase conceptions of best practices	Challenges described at end of assessment phase
Full team (10–12 students)	Keep an open mind, Follow up with stakeholders			Account for diverse perspectives, Leverage local connections	Understanding the context, Optimizing short time in community
$\frac{3}{4}$ of team (7–9 students)		Justify identified needs, Follow up with stakeholders	Overcoming team biases	Compare data across team	Accessing stakeholders
$\frac{1}{2}$ of team (4–6 students)	Identify potential needs in advance	Conduct research to help build rapport, Have a plan	Practicing assessment skills, Finding contextual information, Optimizing short time in community	Avoid biasing data collection, Keep an open mind about needs	Recording data during fast-paced interactions
$\frac{1}{4}$ of team (0–3 students)	Don't cross boundaries, Let stakeholders guide conversation, Conduct research to understand culture, Communicate across team, Visit other places and compare data	Identify questions to ask, Be solution neutral, Avoid offending stakeholders, Identify appropriate scope of needs	Managing extensive data, Navigating language barriers	Adopt flexible data collection approach, Take good notes	Evaluating needs, Executing recommended practices from training, Identifying appropriate needs, Navigating language and cultural barriers

tions that related to identifying how their own subjectivity influenced their process. For instance, the suggestion *Keep an open mind* during beginning of pre-assessment phase group interviews represented a first step towards recognizing that a designer's pre-conceived notions about needs may bias the approach that the designer takes when evaluating needs [2, 4–6, 30]. Several participants also acknowledged that collective group biases might influence the team's perception of community needs when discussing *Overcoming team biases* as an anticipated challenge after completing the C-SED module. Finally, participants developed an approach during their assessment activities, *Compare data across team*, that helped them manage their individual subjectivities when interpreting data and identifying community needs. However, participants did not discuss any strategies that would help them similarly account for their collective group subjectivities as part of their needs assessment process, indicating a potential knowledge gap compared to descriptions of this best practice in the literature [2–6, 27, 29].

Collect many different types of data [1–6, 29]. Conceptions related to collecting many different types of data did not emerge, likely because the team had initially expected to be collecting only observational data and thus only prepared to conduct observations. While participants described a few anecdotal examples from their assessment phase of observing objects or activities that contradicted earlier stakeholder responses, they were generally unsure how to manage these inconsistencies. Participants also encountered difficulties associated with *Recording data during fast-paced interactions* that may have impacted the team's ability to reflect on their data collection process and develop conceptions associated with this best practice.

Select data collection methods based on specific criteria [1, 2, 4, 5, 29]**.** A few participants described conceptions related to selecting data collection methods based on specific criteria. For instance, since participants expected to conduct observations in clinical settings, the conception *Don't cross boundaries* during beginning of pre-assessment phase group interviews represented a justification for prioritizing etic observations over emic observations or interviews with clinicians. However, this best practice was not covered in depth as part of the C-SED module. In addition, participants struggled to *Find contextual information* about the community. As participants described during end of assessment phase individual interviews when discussing the *Understanding the context* challenge, the inability to find in-depth information about the partner community in advance impacted the team's ability to plan out and justify their data collection approach. Our participants' struggles with understanding the community context thus limited opportunities for them to develop conceptions related to this best practice as part of their pre-assessment and assessment activities.

Interact with a wide variety of stakeholders [1–6, 27, 29]**.** While interacting with a wide variety of stakeholders was discussed extensively as part of the C-SED module, participants did not describe conceptions related to this practice until the conception *Account for diverse perspectives* during end of assessment phase individual interviews. This conception emerged because the team encountered divergent stakeholder perspectives while collecting data in their partner community. As described in another study based on this data set [59], the divergent stakeholder perspectives encountered by the team spurred reflective behavior in participants that translated into new conceptions related to interacting with a wide variety of stakeholders. However, while participants learned how to recognize and interpret differences in community perspectives, few participants discussed how they might reconcile divergent perspectives when defining community needs or how addressing community needs might impact various stakeholders differently. In addition, the difficulties associated with *Accessing stakeholders* and *Optimizing short time in community* restricted the variety of stakeholders that the team could interact with in practice, meaning that participants had few opportunities to develop their conceptions of this best practice further.

Develop rigorous metrics to evaluate and prioritize needs [1–6]. Participants touched on developing rigorous metrics to evaluate and prioritize needs when describing how they should *Justify identified needs*. This participant conception indicated an awareness that needs are diverse and rigorous metrics may be needed to compare needs. However, participants discussed few concrete strategies for comparing and filtering needs, which was notable given that strategies drawn from Zenios et al. [3] and Sienko et al. [15] for comparing and filtering needs were discussed extensively as part of the C-SED module. Participants also did not describe methods for systematically analyzing the data that they did collect, beyond *Comparing data across team* to establish shared interpretations of the team's data.

Engage community or organization as equal partners [2, 3, 27, 29, 31]. Participants described one aspect of engaging the community or organization as equal partners when they discussed *Following up with stakeholders* during beginning and end of pre-assessment phase group interviews. As was suggested by participants, verifying needs assessment findings with the community is an important part of

engaging the community as partners in the needs assessment process [2, 3, 27, 29, 31]. At the end of the team's assessment phase, participants also discussed the importance of *Leveraging local connections*, especially the team's guides. This second conception represented a step towards closely involving partners in needs assessment activities, another important aspect of engaging the community [2, 3, 27, 29, 31]. While participants did not discuss methods for building partner capabilities, this aspect of the engage community best practice was not covered as part of the C-SED module.

In summary, many participants had initial ideas related to identifying their own subjectivity and engaging the community as equal partners. Participant conceptions related to these best practices from the literature continued to develop throughout the team's pre-assessment and assessment activities, although there were a few gaps in these conceptions that future iterations of the C-SED's needs assessment module [26] might address. The team's assessment experiences were also instrumental in helping participants develop conceptions related to interacting with a wide variety of stakeholders.

However, participants discussed few conceptions of best practices related to collecting many types of data, selecting data collection methods based on specific criteria, or developing rigorous metrics to evaluate needs. The limited participant conceptions related to these three literature best practices may explain why several participants felt unsure about the community needs they had identified; participants felt that they did not have sufficient data after one week in the partner community and made potentially risky interpretive leaps when describing needs.

5.2 Assessment Challenges Related to Cross-Cultural Context

The three challenges cited most frequently by participants in end of assessment phase individual interviews – *Understanding the context*, *Optimizing short time in community*, and *Accessing stakeholders* – may be characteristic of many cross-cultural projects. These challenges present unique difficulties that must be accounted for as part of a team's needs assessment process. For example, participants described difficulties finding contextual information about the partner community, particularly on the internet, that could guide the team's plans for data collection. Many cross-cultural design projects occur in small, rural and remote communities (e.g., [8, 10, 25]) similar to the one where our participants collected data. Logically, other project teams working in cross-cultural contexts should have encountered similar challenges with researching the partner community in advance. However, such challenges are rarely reported, perhaps because many cross-cultural project descriptions focus on the stakeholder research that was ultimately conducted rather than how the design team prepared to conduct this research. One study on how students gathered information on their stakeholders for cross-cultural projects (Garff et al. [49]) found that their participants, like the participants in our study, did not leverage online resources much to gather information about stakeholders because there was little relevant information available. Instead, the participants in Garff et al. [49] were more likely to seek information directly from local partners. While local partners can be a great source of otherwise difficult-to-find information during the pre-assessment phase [2], participants in our study did not think to ask their guides for more contextual information about the community until after they were already in the partner community.

While local partner involvement in pre-assessment contextual research is ideal, close communication with local partners may not always be possible. In such cases, there are several other potential sources that designers might leverage to conduct contextual research. For instance, designers might research needs that are experienced in similar communities [1] and previous solutions to these needs [3, 10]. This type of contextual research can help designers develop standards of comparison that may help them identify unique needs once they enter the partner community. In addition, research into other previous needs assessments might help designers think about relevant types of data to collect [1, 2, 10], or identify how their implicit conceptual models might be influencing their initial ideas about community needs [6, 10, 21]. This type of research could have helped participants in this study be more intentional in selecting their data collection methods during their pre-assessment phase. Finally, designers might look for macro-level information, such as census data or information about available services, that could facilitate identification of preliminary needs [4, 60]. This information could help establish a baseline for what designers should expect to see in the community, which may lead to surprising insights during assessment activities if the census or services information does not match reality.

In addition, the time and access challenges encountered by participants in this study are not uncommon for cross-cultural design projects but may point to a tension that is unique to needs assessment activities. For instance, full needs assessments typically occur over months or years [1, 2, 4, 27], although some sources (e.g., Darcy & Hoffman [6]) discuss a more rapid approach for quickly

prioritizing necessary knowledge in crisis situations. A long time frame allows the needs assessment team to collect enough data and interact with enough stakeholders to develop comprehensive descriptions of community needs. However, one to two-week data collection experiences are common for cross-cultural design projects involving students due to the restrictive realities of cost, distance and student schedules (e.g., [46, 48, 55, 61]). From one perspective, these short experiences can lead to substantial learning gains for students, similar to the gains observed in this study [46, 48, 61]. However, there remains a question as to whether valid community needs can be identified in only a week or two [1, 3, 10].

Faced with challenges related to time and access, recommendations include relying on local partners to collect additional information [55, 61] or having a team representative stay in the community for several months as a semi-permanent liaison [56]. However, students may struggle to acquire timely or accurate information from local partners because these partners often have their own important responsibilities in the community [46]. As such, while continued contact with local partners is certainly important, engineering students would also benefit from pedagogical structures that could help them both navigate limitations related to time or access to stakeholders in the community and also set project goals that properly account for these limitations.

5.3 Limitations

One potential study limitation was the unique composition of the needs assessment team. The team represented a diverse collection of different engineering disciplines, and many participants were also pursuing non-engineering double majors or minors. The diversity of disciplinary perspectives available to the team may have helped participants develop conceptions of best practices related to recognizing their own subjectivity that perhaps would not have emerged on a team with less disciplinary diversity [10]. On the other hand, the team exhibited little gender diversity with eleven out of twelve participants identifying as female. It is unclear how our findings would change in the context of a team with more gender diversity, or in the context of a team composed primarily of men.

Another study limitation was that we did not directly track the activities of the team while they were collecting data in the community. As such, we are unable to verify how participant descriptions of needs assessment activities corresponded to what the team did in practice.

A third limitation was that the end of assessment phase interviews completed with each participant occurred right after the team returned from collecting data in the partner community. At this point, assessment experiences were still salient and participants could easily describe what they had learned. It is unclear which learning gains from the needs assessment experience have continued to be salient over time, especially since participants did not have consistent additional opportunities after this experience to practice what they had learned [62].

5.4 Implications for Design Pedagogy and Practice

One implication of this study is that design educators can use the needs assessment framework (including general process and best practices) described in Sections 2.1 and 2.2 to develop pedagogy for student teams that are performing needs assessments. While the main focus of our study was on needs assessments in cross-cultural contexts, the framework presented in this paper is likely transferrable to situations where engineering students are conducting needs assessments within cultures more similar to their own [1, 3, 4]. For example, Lima [63] has described how identifying the ways that a designer's subjectivity influences their process, interacting with a wide variety of stakeholders, and engaging the community as equal partners helped engineering students identify and evaluate needs as part of local community-based design projects. Furthermore, the in-depth case example presented in our findings and discussion highlighted which needs assessment best practices some engineering students might already have an intuitive understanding of, such as engaging the community, and which best practices some engineering students may struggle with, such as developing rigorous metrics to evaluate needs.

The study findings also suggest that engineering students need support when specifying goals for their needs assessments. Effective teams specify clear goals at the outset of the needs assessment; these goals help the team identify key stakeholders and develop their data collection plan [1–6, 27]. Specifying clear goals is vital for cross-cultural needs assessments because clear goals can help designers navigate challenges related to finding contextual information and time or access constraints. Meanwhile, teams that are less explicit about their goals may struggle to identify community needs that can reasonably be addressed and may unintentionally mislead partner communities or organizations about the timeline of potential solutions. While the specific contexts of cross-cultural student projects may differ, the challenges experienced by the team in this study are likely transferrable [1, 2, 6]. As such, other design teams and educators could use this case to help them specify appropriate needs assessment goals given

constraints on time, access, and available contextual information.

Finally, our findings suggest that engineering students that are interested in conducting needs assessments for cross-cultural design projects may need more curricular instruction in applying qualitative data collection methods and analyzing qualitative findings. Certain design questions, especially those related to identifying stakeholder needs, are best addressed through qualitative research and analysis. However, participant challenges with collecting many types of data, selecting data collection methods to use, and developing rigorous metrics to evaluate needs point to a gap in student knowledge related to applying qualitative methods and analyzing findings. Previous studies have reported similar gaps in student knowledge, for instance in the context of capstone courses [64, 65]. However, in the context of this study, participant knowledge gaps related to collecting and analyzing qualitative data directly impacted participants' abilities to assess community needs properly.

6. Conclusions

This study followed an undergraduate engineering team as they conducted a needs assessment to understand what these students already knew about needs assessments, how they conducted a needs assessment in practice, and their learning gains from experience conducting a needs assessment. Participants expanded their understandings of best practices related to identifying their own subjectivity, engaging the community as equal partners, and interacting with a variety of stakeholders. However, participants did not describe many conceptions related to collecting several different types of data, selecting data collection methods based on specific criteria, or developing metrics to evaluate needs. As a result, participants felt that their assessment phase was successful but at the same time were unsure whether they had collected enough data to identify community needs effectively and did not know how best to select a need to address going forward. These findings suggest that engineering students engaged in cross-cultural design projects would benefit from additional pedagogical support for specifying project goals, collecting qualitative data related to these goals, and analyzing these data. Best practices for needs assessments synthesized from the literature and described in this paper, as well as our descriptions of student challenges, can support the shaping of this pedagogy to help engineering students develop skills to apply when working on cross-cultural design projects.

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