

Work in Progress: Experiences of Uncertainty in Sociotechnical Small-Group Undergraduate Discussions

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Abstract: In this work-in-progress qualitative case study, we explore how first- and second year undergraduate students experience uncertainty when doing expansive thinking in sociotechnical engineering modeling work. For this purpose, we analyze stimulated recall interviews of four students to identify the different ways in which they experienced both relational and epistemological uncertainty during an in-class discussion activity.

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Introduction

The status quo in engineering is dominated by narratives of technocracy and depoliticization (Cech, 2014), and it privileges capitalistic, neoliberal, and free market ideals (Riley, 2008). Applied to engineering education, this status quo de-emphasizes the social and political aspects of engineering work and often reduces engineering problems to tasks that require only technical expertise (Gunckel & Tolbert, 2018; Cech, 2014). However, in reality, engineering practice is always embedded in complex social and political situations, which both inform design choices and influence the outcomes (McGowan & Bell, 2020; Riley, 2008).

For engineering practice to center issues of social justice, future engineers must learn to center the contexts in which their design takes place and consider different sociotechnical possibilities (Cech, 2013; Riley 2008). They must engage in *expansive thinking*, which entails breaking free from “status quo narratives and attend[ing] to science and technology from a human-centered, systems-level perspective” (Radoff et al, 2022, p. 2). This breaking free requires engineering students to rethink what socio-political and economic values and perspectives are being included in engineering from the standpoint of social justice and equity. For students, opportunities to question dominant narratives and values prevalent in engineering design can prompt acute feelings of uncertainty around the process and outcomes of engineering work (Baillie & Armstrong, 2013).

In our research, we ask, how do different kinds of uncertainties mediate the expansive moves that students make in a sociotechnical small group discussion? In our previous research (under review) we characterized the expansive moves that a group of five students made during an in-class discussion. In this WIP paper focusing on the same small group, we ask, *In engineering modeling work, how do these undergraduate students experience uncertainty during their expansive sociotechnical discussion?* Using stimulated-recall interviews, we look closely at how the different students report experiencing uncertainty.

Theoretical Framework

Given the socio-cultural nature of knowledge and learning, students negotiate what it means to learn and do engineering through their interactions in-the-moment (Philip, 2018). For example, a student on a design team may experience pushback when advocating for their team to consider community impacts of a prototype they are constructing. These negotiations may raise different kinds of uncertainty about what ideas are valid and whose contributions are relevant. In this study, drawing on Jordan and McDaniel’s (2014) work, we explore how students experience relational and content uncertainty when engaged in expansive thinking. Jordan and McDaniel define uncertainty as “the subjective experience of doubting, being unsure, and wondering how the future will unfold or how to interpret the past” (p. 492). Relational uncertainty encompasses how people in a given social context experience uncertainty about the opportunities and challenges available to them; this also relates to their identity work. For example, students may wonder whether they are being heard in the group and if they belong in a particular community

of practice. Content uncertainty includes questions about the ideas, approaches, or intended end result of an activity. This type of uncertainty is similar to what Hartner-Tiefenthaler et al. refer to as epistemological uncertainty, which they define as a “subjective feeling of being unsure about the content, process or outcome of a task.” (p. 21, 2018). We adopt the latter term, epistemological uncertainty, to reflect that questions about process can include questions about what counts as valuable ways of knowing and doing engineering.

Maintaining epistemological uncertainty in engineering work is an inherent part of expansive thinking. As students make space for including social, political, and economic aspects in engineering work, they question what is valuable (what should be foregrounded) and how they can include these aspects. By maintaining uncertainty, they explore new sociotechnical imaginaries of what designs are possible, especially from the standpoint of equity and social justice. These uncertainties are not static and are not necessarily shared between all members in one group. At any given moment, students’ uncertainty may be raised, dismissed, ignored, or acknowledged (Jordan & McDaniel, 2014).

Methods

This study is part of a larger NSF-funded project to integrate sociotechnical thinking into a first-year engineering computing course. Redesigned components support students in identifying and critiquing the social, political, and economic decisions in engineering from a social justice lens. In the course, students work on five major socio-technical coding projects. They are also provided with readings and frameworks to question narratives of technological neutrality and center the differential impacts of technology. In this study, we consider classroom data from a single small-group discussion held during the Water-Energy-Land modeling and optimization project. As part of this project, in one class students were asked to discuss and determine (1) positive and negative impacts from decisions about the use of water from rivers shared between two fictitious countries, (2) what to include in a computational model designed for optimizing water management, and (3) how to quantify some of these aspects. The authors were involved in designing but not teaching the course

In another study (Rahman et al, 2024) we explore the discourse moves made during the small group discussion by five women in this class to engage in expansive thinking. These expansive moves included (1) highlighting key contextual differences within the framing of the problem, (2) acknowledging task difficulty and uncertainty (3) agreeing to try despite the uncertainty, (4) putting forward bids for ways to quantify, and (5) reframing the problem to simultaneously include multiple contextual elements. In this present study, we explore the self-reported subjective experiences of four of the students (Table 1, one student declined to be interviewed), including how each saw their own contributions in the group discussion and the uncertainties that they wrestled with. Data sources include video of the in-class discussion and stimulated recall interviews in which the students were shown clips of the video and asked questions like what stood out to them about their group’s work on the task, to what extent they agreed with their teammates’ ideas, and how comfortable and engaged they felt.

Data analysis procedures included interaction analysis (Jordan & Henderson, 1995) of the recorded discussion, with memo writing and discussion of the tentative findings in small and

large research group meetings. The first author conducted a thematic analysis (Braun & Clarke, 2006) of the interview transcripts for students' experiences of uncertainty, beginning with open coding and then shifting to focused structural coding. The second and third authors periodically met with the first author during this process to co-analyse the interview findings and refine the themes. We paid special attention to markers of uncertainty including, "I don't know," "I think, and "I am not sure." Subsequently, we identified the different ways in which the students experienced epistemological and relational uncertainty.

Table 1: *Details of Study Participants*

Pseudonym	Gender	Year	Race/Ethnicity
Sharon	Woman	1st	White
Arami	Woman	1st	Hispanic [From Paraguay]
Heba	Woman	1st	[From Egypt]
Adya	Woman	2nd	South Asian

Findings

In their interviews, Arami, Adya, and Heba revealed they had experienced epistemological uncertainty as they considered (1) what their water-energy-land modeling process should be and (2) what their outcome could look like. In contrast, Sharon's interview responses did not indicate epistemological uncertainty, but did indicate relational uncertainty. Even though the recording of the discussion seemed to show Sharon participating in-the-moment, in the interview she reported intense feelings of not being viewed as a contributor.

Epistemological Uncertainty

In their in-class discussion, the students in this group talked about including two main aspects of the water-land-energy problem in their computational model: energy distribution and transboundary equity. Energy distribution focused on the efficiency of electrical energy delivery. Transboundary equity focused on mitigating political tension between two countries and equitably sharing benefits and harm between countries, given that the dam was built in one country only.

In her interview, Heba mentioned that she wanted the group to consider the aspect of transboundary equity even though they were already working on quantifying energy distribution. The video of the in-class discussion reveals that Arami pushed back against Heba's bid by emphasizing that they needed to quantify whatever aspect they were going to consider, and that it would be difficult to quantify transboundary equity. Arami's challenge made Heba doubt whether her idea to consider transboundary equity was relevant to the work the group was doing. In her interview, Heba said,

For example if country A has the dam [...] country A gets this energy. So somehow I thought that country A is getting more advantage than country B. So, I wanna make this advantage distributed, kind of split among both countries in that context. So, I was trying to suggest a solution where we can have country B but [...] I didn't understand [...] **So, we were talking about the statistics and then I**

suggested a different thing which is not quite related to what we were discussing. I'm not sure.

During this in-class moment, the group had wrestled with whether they should continue to focus on quantifying energy distribution or consider how they could include the 'hard to quantify' aspect of transboundary equity. As Arami reflected in her interview, the group was establishing *what* they had to do and *how* they would actually do it:

No, we have to do energy distribution, and it was like, no, we don't need to do only energy distribution. [...] **So, it was establishing [...] what do we have to do? And how are we going to actually do it?** (Arami)

Subsequently, for the group to include transboundary equity they had to engage with two questions: are aspects that are 'hard to quantify' relevant? And, how can we quantify these aspects? In the in-class discussion, the group resolved the first question by agreeing that it was hard to quantify transboundary equity, but that they would still try. In their interviews, Arami, Heba, and Adya expressed grappling with epistemological uncertainty on whether and how the aspect of transboundary equity could be quantified:

We were going to talk about the [...] political relationship. **But like, how do we actually quantify that?** Because we were supposed to create a formula for something and quantify it. (Arami)

How do we quantify these aspects that we brought up? So, like any point that was brought up [...] like energy distribution or just impact. We still got to a point [...] 'How are we going to quantify these?' And then we talked about both points and then were like, which one would make more sense to quantify or like be easier to quantify. (Adya)

I am not sure the idea I suggested can be statistically quantified, but yeah. (Heba)

Here we see Arami, Heba, and Adya wrestling with the epistemological uncertainty of whether they could include transboundary equity and how they would include it. Establishing the relevance of including transboundary equity went hand in hand with the continuing uncertainty of how this aspect could be quantified.

Relational Uncertainty

Unlike Adya, Heba, and Arami, Sharon expressed relational uncertainty around (1) whether her ideas were being heard and acknowledged in the group, (2) if she was being taken seriously, and (3) whether she was seen as a member of the engineering community by her group mates.

In her interview, Sharon shared that she "did not at all feel heard in the group" and she didn't "really know why that was." These feelings of being unheard linked with her feelings of not being "taken seriously." She said,

I definitely feel like [...] it was hard for me to have somebody acknowledge what I would say. **I don't know, I just felt like I genuinely wasn't taken seriously by my group.** But I think that's - I don't know what level that is. That's just how I felt a lot of times they wouldn't acknowledge what I would have to say.

When asked if there was something she would have liked the group to also consider while wrestling with the question of what aspects they should focus on, Sharon answered that she might have, but that she did not feel like she was a “relevant person” in the group's conversation to share:

I felt like I didn't necessarily have something [...] - that I could compare to. You know what I mean? So that made me feel like, okay, maybe **I'm not like as much of a relevant person in this conversation** or I even can have much of an opinion because it's not personal to me. Which I don't agree with, but I think that's, you know, how I was feeling in the moment.

Sharon also highlighted the uncertainty around the “level” to which she was not taken “seriously” by the group and conjectured that her ideas would not be “heard as much as if somebody else says it.” These feelings of exclusion in the group were also linked with her identity as an engineer:

I don't know. I feel like - just like the stereotype of an engineer is not something that I really fit. **And I feel like a lot of my engineering peers just don't take my - take me seriously.** That's something I've struggled with. And then in that class, I was like, I feel I have to change some of these things just so I can be taken more seriously and they can see me more as like a member of their community instead of like [as] somebody who looks and like doesn't seem to belong here.

Sharon's feelings of being “excluded” meant that she “pulled back” from the group, refrained from asking questions, and questioned whether she had any “valid opinions.” She shared that she was not a part of “directing” the conversation but was just “trying to hop in wherever it was directed.” When asked what she would have liked to contribute to the conversation if given a chance, she said,

I think it was just like, kind of having the time to say something because it was a discourse that was just kind of like very back and forth.

Here, Sharon highlighted that she was not given the space to bring up new ideas or to direct the conversation, so she settled for trying to make contributions that would be “kind of relevant” to the group's discussion. In contrast, Heba and Arami felt that they had space for their ideas to be heard, challenged, and built upon. Heba and Arami both reported in their interviews that they appreciated each other for challenging each other's ideas and helping them adopt different perspectives. Heba described her group's dynamics to be “amazing” as everyone was “respectful” and could ask questions and better “understand each other.” Arami shared that she “loved” Heba as she would bring her “back to earth” and would challenge her by saying, “You

know you're talking about this, but we need to do this.” Adya, too, when asked if she felt comfortable disagreeing with her group members, replied that everyone was “super comfortable voicing” their different ideas.

Discussion

We analyzed student interviews to identify the different kinds of uncertainty experienced by individual students as their group collectively made space for expansive thinking during an in class small group discussion. Students' experiences with epistemological uncertainty co-occurred with a relative lack of relational uncertainty.

Heba, Arami, and Adya's engagement with epistemological uncertainty meant that they could collectively question and consider possibilities for including different aspects, especially those that were hard to quantify, like transboundary equity. Given that complex social and political contexts are often considered tangential to engineering work (Cech, 2013), we see the students questioning what and how to value different political aspects in their engineering modeling as productive beginnings of questioning the sociotechnical dualism prevalent in engineering. In their in-class discussion, the group's agreement to try to quantify aspects of transboundary equity meant that the students had to engage with uncertainties relating to the process and outcome of including political aspects in their engineering modeling work. Subsequently, wrestling with this epistemological uncertainty created space for the group to engage in different sociotechnical possibilities.

However, Sharon did not engage in this epistemological uncertainty. For her, relational uncertainty took precedence and subsequently, she did not feel like she had the space to form her ideas. Given that knowledge is co-constructed, for groups to come up with new ideas and practices there must be space for students to collectively engage with the process and outcome uncertainties (Hartner-Tiefenthaler, 2018). Sharon's exclusion from the group not only meant that she did not have space to formulate her nascent ideas with the group, but also that she did not share her team members' epistemological uncertainties. In contrast, her group mates, who did not experience this relational uncertainty, felt comfortable voicing their nascent ideas and questions in the group, and publicly wrestled with epistemological uncertainties, which made space for different sociotechnical imaginaries. The space for rethinking and reimagining felt off-limits to Sharon, whose wonderings focused less on whether her ideas were relevant but rather on whether she herself was a “relevant person.” Prior research also suggests that overcoming relational uncertainty makes space for deeper engagement with epistemological uncertainty (Hartner-Tiefenthaler, 2018).

This conflicting relationship between epistemological and relational uncertainty has important implications when it comes to who and what ideas get included in a group's collective sense-making and knowledge creation work. Unresolved relational uncertainties may exclude students from engaging with epistemological uncertainty and thereby limit opportunities for students to question and rethink dominant narratives and practices in engineering. It is also important to note that it is not evident from viewing the in class discussion alone that Sharon was being excluded from the conversation, as Sharon never expressed her relational uncertainty. This raises questions around how students come to understand what uncertainties are okay to express in a space. In our future work, we aim to explore further the group dynamics in relation to what

uncertainties were expressed and not expressed. We also seek to draw more connections between the moves students made for expansive thinking and the uncertainty they experienced.

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