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Making Space for Expansive Thinking in Socio-Technical Small-Group Undergraduate Discussions

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Abstract: In this qualitative case study, we explore how first- and second year undergraduate students make space for expansive thinking in their engineering modeling work. We focus on the ways in which one group of five women negotiated the inclusion of different social, political, and economic factors in their design model, particularly energy distribution and transboundary equity. Drawing on discourse analysis methods, we analyzed a small-group in-class discussion and identified five expansive moves that helped the students to make space for rethinking what they could include in their model. These included being explicit about their assumptions and uncertainties and acknowledging task difficulties.

Introduction

Engineering is generally presented as apolitical, asocial, and neutral, and engineering problems are often reduced to technical considerations where socio-political complexities are deemphasized (Gunckel & Tolbert, 2018; Cech, 2014). In reality, engineering is informed by social, political, and economic values and commitments (McGowan & Bell, 2020; Riley, 2008). Supporting undergraduate engineering students in adopting a socio-technical lens is difficult, especially when they learn over the course of their degree programs to separate engineering from political and social issues and when dominant narratives of depoliticization prevent students from adopting more justice-oriented framings (Cech, 2014). In this paper, we develop a descriptive case study to address the research question, *in engineering modeling work, how does one group of undergraduate students make space in their discussion for expansive thinking, in this case, including different socio-political perspectives?*

Theoretical framework

We draw on Radoff and colleagues (2022) work on expansive thinking, which they define as the breaking free from "status quo narratives and attending to science and technology from a human-centered, systems-level perspective" (p. 2). They highlight the need to rethink dominant narratives and values prevalent in engineering. Given the socio-cultural nature of knowledge and learning, these status-quo narratives are not static, but rather are contested and reinforced through interactions. Students negotiate what it means to learn and do engineering through their interactions in-the-moment (Philip, 2018). Therefore, to explore how students contest the status-quo boundaries between the socio-political and technical, we conduct a micro-genetic analysis of student discussions (Gee, 2010). We focus on the bids and responses that one group of students made that facilitated rethinking what and how different socio-political aspects are being privileged in their model. We label these successful bids as "expansive moves" as they de-center dominant narratives, such as those of technocracy and depoliticization, and push for a systems-level perspective that makes space for more expansive socio-technical imaginaries.

Methods

This study is part of an NSF-funded project to redesign a first-year engineering computing course to make visible and critique the socio-political decisions in engineering through a justice lens. Students are provided with readings and frameworks to question narratives of technological neutrality and to center the differential impacts of technology. We focus on one small group (Table 1) as they engage in an in-class discussion during a Resource Optimization project. Students were asked to critique and revise a provided water optimization model for two fictitious countries. In the discussion, students considered (1) how different stakeholders would be impacted by different scenarios (2) what aspects should be included in the computational model and (3) how some of these aspects could be quantified. The authors were involved in designing but not teaching the course.

In the first phase of analysis, we reviewed the video recording and transcript of the students' discussion in multiple research group meetings, looking for moments when the students grappled with the social, political, and economic aspects of engineering. The first author wrote descriptive and analytical memos of the episode (Corbin & Strauss, 2015). We found that students considered four main aspects: (1) energy distribution, (2) economic distribution, (3) transboundary equity (consideration of issues of equity between two countries), and

(4) water distribution. Two researchers then independently coded the students turns of talk for instances when the students mentioned or sustained discussion on one or more of these aspects. Consensus was reached to resolve any disputes. This turn-of-talk analysis enabled us to identify a 10-minute segment where the students initially left behind and then re-considered transboundary equity. We conducted a micro-genetic discourse analysis (Gee, 2010) to identify expansive moves that facilitated the students rethinking of the aspects included in their model. Here we develop a descriptive case study (Yin, 2009) to showcase the rich work of this one group of diverse women that made space for expansive thinking.

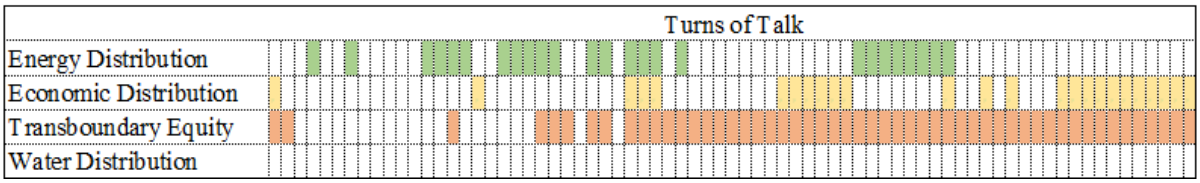
Table 1
Details of Study Participants

Pseudonym	Gender	Year	Self-Reported Ethnicity
Steph	Woman	1st	East Asian
Sharon	Woman	1st	White
Arami	Woman	1st	Hispanic [From Paraguay]
Heba	Woman	1st	[From Egypt]
Adya	Woman	2nd	South Asian

Findings

As the students considered how to quantify aspects they had identified for their model, they initially considered the aspect of transboundary equity but quickly moved to equitable energy distribution instead (Figure 1). This shift was initiated by Arami, who made concrete suggestions for quantifying equitable energy distribution by considering energy production, distribution, outages, and costs. Adya and Sharon quickly accepted this bid by talking more concretely about the formulas they could use. Later, however, the conversation shifted back to considering transboundary equity. This time, students considered how they could reduce harm to the country downstream and ensure an equitable sharing of resources and benefits between the two countries. Below we identify this group's expansive moves that made space for this re-thinking.

Figure 1
Students Turns of Talk Focused on Each Aspect During Small-Group Discussion on Defining Model Behavior.



Highlighting key contextual differences

As the group was converging on ways to quantify equitable energy distribution, Heba made a bid for the group to re-consider the transboundary equity of building a dam. This bid stemmed from the group's earlier concerns around whether economic benefits from a dam would be equally shared between the two countries. Arami had maintained that these benefits would be shared as she was envisioning a dam in the middle of two countries, like in the case of Paraguay and Brazil. In her bid, Heba leveraged her own experience of the Renaissance Dam to point out why contexts other than Paraguay and Brazil should also be considered in their model. She said,

> Heba: But for example ... the Renaissance Dam, which is not [in] Egypt, affects Egypt …. We are talking about energy distribution in case the dam is built in both countries [Paraguay and Brazil]. But …the majority of cases are where the dam is built [in] a different country and the rest of the countries …will be impacted in a different way.

In response, Arami suggested they could continue to work on energy distribution between the two countries and address transboundary equity within that focus. However, Heba pushed back against this bid and asked the group to adopt a more "general" framing of the problem, one that looked at multiple impacts of the dam on both countries. She suggested instead that transboundary equity could encompass energy distribution and other aspects like job opportunities. Here, Heba made space for rethinking what aspects the group was including by naming and challenging the context of the scenario on which the group was basing their model decisions.

Heba: Oh, just it is a good point that we think about energy distribution, but we can make it more general … how the dam will impact like both countries. So, for country A, maybe they will have more energy … or country B … there may be some new policies that make countries work together and share … energy or hire workers from the country B. So, the change here may be in the policies between the two countries. I guess.

Acknowledging task difficulty and uncertainty

Following Heba's bid, the group considered the difficulty of quantifying transboundary equity. Arami made clear the decision facing the group: whether to continue working on quantifying energy distribution or shift focus to transboundary equity. Sharon acknowledged that quantifying transboundary equity would be hard, and Arami elaborated on what would make the task hard: they would need to create a formula using numbers. The implication was that considering political aspects might not be the best course of action for the group. In these exchanges we see the group explicitly wrestle with the uncertainty of whether transboundary equity fits within the realm of quantified engineering models.

Arami: …Do you want to quantify that? Because that is what we need to do.
Heba: Yeah, we need to quantify.
Sharon: It is hard to quantify it.
Arami: Quantify something like create a formula and quantify that. Like in numbers.

Agreeing to try despite the uncertainty

Just as it seemed like Arami was shutting down Heba's bid, Adya stepped in to maintain the uncertainty around including and quantifying aspects of transboundary equity. As a result, the group made an agreement to "try." This social agreement opened up space for the team members to grapple with the uncertainty of how they would quantify something as nebulous as transboundary equity within their more concrete model.

Adya: We can try.
Arami: We can try.
Heba: We can, yeah, we can. Okay, we can, we can.

Suggesting some ways to quantify

Adya then provided more support to Heba's point by summarizing it and suggesting a way forward. She said,

Adya: So, you are talking about how if the dam is built in only one country, what's going to be the relationship between the two. And how do you make it even? And like one way to make it even, would be create, create job opportunities for the non-dam country.

Here, Adya's revoicing of Heba's bid helped maintain the group's focus on reconciling the seemingly disparate worlds of transboundary equity and quantified engineering modeling. In her revoicing she made three key moves. First, she reiterated the main difference in the context: the dam is built in only one country, not between both countries. Second, she identified the group's task: to consider the relationship between the two countries with a goal of "even[ness]". Third, she offered one example of a way to quantify and "make it even" between the two countries: through job opportunities.

Reframing to simultaneously consider multiple aspects

Finally, Adya re-framed their modelling work so that transboundary equity would be treated as a more general objective that would encompass the other aspects of energy and economic distribution.

Adya: Wait, wait you can still leave that in there we can do multiple … Maybe … we want our focus to be the relationship between the two countries now … more than like energy distribution, [be]cause under

the umbrella of the relationship between the two countries is also going to be cost, and political tension, and also energy distribution.

Discussion

During this discussion in an introductory engineering computing course, five expansive moves made space for the students to rethink the exclusion of transboundary equity from their model behavior. These moves involved explicit naming and challenging of assumptions on the model contexts, acknowledgement of task uncertainty and difficulty, and a re-framing of the problem.

Engineering design priorities are rooted in assumptions about the contexts of the design, and if left unchallenged tend to perpetuate historical inequities (Costanza-Chock, 2020). Heba's bid to re-consider transboundary equity made space for the group to rethink their model priorities as it named the specific context that the group was considering and made explicit the limitations of that context. Subsequently, it helped center equitable sharing of benefits and harm between the two countries as an important design priority. We see *highlighting key contextual differences* as an expansive move that made explicit the contextual assumptions and necessitated a rethinking of design priorities to include transboundary equity.

Given that dominant narratives in engineering tend to privilege what is easily quantifiable and exclude social and political aspects, there is an increasing need to include these aspects within the modeling work that engineers do. The students in this study productively wrestled with integrating the social and political into enginering modeling decisions. In their efforts to prioritize transboundary equity while reconciling demands for quantification, they began to contend with disciplinary uncertainty – if and how can transboundary equity be included within the design of engineering models. The students' moves of *acknowledging task difficulty and uncertainty*, *agreeing to try despite the uncertainty,* and *suggesting ways to quantify* were expansive moves that made space for the students to negotiate traditional boundaries between the social, political and technical in engineering and engage with different socio-technical imaginaries.

Finally, the students made space for re-thinking the exclusion of transboundary equity by *reframing their design goals*. While initially the group's framing considered energy distribution, they later centered the modeling problem around transboundary equity. This reframing allowed the students to adopt a systems-level approach and simultaneously consider multiple aspects of the modelling problem.

Conclusion

As a small group of five women undergraduate students discussed what to include in their model for optimizing water management, they made explicit their own contextual assumptions and uncertainties. While these moves are specific to this one group of students, they reveal the productive wrestling that other students might also encounter during expansive thinking. Our findings suggest that instructors might make more space in their classrooms for students to recognize the task difficulty and uncertainty surrounding sociotechnical work, while encouraging students to make explicit and critique their assumptions and model priorities.

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