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Supporting First-Year Students to Set Engineering Requirements

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Abstract

In this Education Research and Assessment Paper, we present results from a design-based research (DBR) study. While first-year design is now a common approach in engineering, less is known about supporting students to frame problems, especially setting engineering requirements. We report on an instructional intervention in the context of an integrative first-year course. Student teams framed problems related to water resilience in New Mexico. Data include student work and video/audio recordings of class sessions. Using qualitative analysis, we investigate how instructional supports helped students frame such problems. Teams posed tentative solutions in order to identify ERs; this can be a foundation for oscillation between solution and problem in the problem framing process.

Introduction & Research Purpose

In the current study, we conjecture that by providing first-year students with a broad authentic, sociotechnical context and scaffolding them to frame their own design problems, students can develop understanding of engineering requirements (ERs) and develop framing agency. Framing agency is the capacity to make decisions consequential to how problems are framed.

While setting requirements is a critical practice for framing engineering design problems, there are relatively few accounts in the research of how students learn to set ERs, rather than just work with ERs given by the instructor or client. We report on a study set in a first-year design course in which we supported students to frame problems related to water resilience, including setting ERs. We were guided by a broad question and more specific subquestions:

- How might a first-year, integrative engineering design project support students to develop and work with engineering requirements?
    - How did the students use their agency in setting requirements?
    - To what extent were their ERs traceable to stakeholder needs? (support validation)
    - To what extent did students set ERs that describe what the solution should embody, not how to do it? (solution independence)

Literature review

Design problems are distinct from other types of problems because they are ill-structured, meaning they have more than one correct answer and, importantly, more than one path to a solution [1]. Before solving a design problem, a designer has to frame the problem by making decisions about the problem itself, including what portions of the design problem need to be focused on, what information is missing, and what the attributes of a successful solution (or the requirements of the solution) are [2, 3]. To more clearly differentiate design problems from other types of problems and understand the role or requirements, we can consider the ways in which such problems are determined [4]. Design problems include aspects that are (a) determined, meaning they have unalterable requirements; (b) underdetermined, meaning the designer must work to set requirements based on what they uncover through research; and (c) undetermined, meaning they are decided subjectively through the designers' preferences and judgment [4].

These undetermined aspects are not limited to aesthetic decisions; they may include central aspects of a design problem. As an example, if we consider the issue of flooding after wildfires, there are varied perspectives that can be taken to frame the problem and set requirements. The problem could be framed as preventing wildfires in the first place, as limiting wildfire spread, as preventing heavy rains, as preventing runoff during heavy rain, or as diverting runoff away from certain areas. The designer's knowledge and experience influence which framing they are likely to pursue, but this is an undetermined aspect of the design process.

Requirement determination is often treated as the bridge between the problem and solution with requirements being revised and narrowed during the problem framing and solving process [5]. Requirements embody the attributes and capabilities of the solution without merely describing a single solution [6]. Thus, requirements don't specify how the problem would be solved or how the solution should work, but what success would look like. They are abstract enough that more than one solution can satisfy any given requirement so that the solution and requirement are not inextricably linked (which is termed *solution independence*) [6]. Requirements then can form the basis of evaluating a potential solution's success.

Requirements allow for mediation between often qualitative expressions of desire from stakeholders [7] as part of the problem to quantitative attributes that can be used to evaluate or test a solution, drawing a clear link between stakeholder needs and the solution [8]. Basing requirements on the interests and needs of stakeholders (as complex and often contradictory as they are) means that requirements *support validation* of possible solutions in light of identified needs. Quantitative requirements support *verification* because designers can determine if the potential solution succeeds or fails to meet that requirement.

The processes of framing a problem and defining requirements involve a multitude of consequential decisions, making the designer highly agentive. Framing agency refers to the ability to make consequential choices about the frame of the problem, including which stakeholders to include or prioritize, which parts of the problem are the most important, and what additional information is needed [9]. While designers use their framing agency to determine the requirements, less is known about supporting students to develop this capacity. In particular, little research has focused specifically on supporting students to set requirements [10], especially compared to other aspects of design education.

It is not uncommon for the instructor or curricula to set the requirements and provide these to students. Or, in some cases, design problems are reduced to their determined and underdetermined aspects [4], such that they may be solved through inductive and deductive approaches alone [11]. While service learning and community engagement are often routes to allowing students to abductively set requirements, in some cases, the descriptions of these activities suggest that students are provided with instructor-set requirements and given constraints and narrowed problem spaces that result in inductively and deductively solved problems. For instance, in collaboration with a children's museum, instructors identified physics concepts and set requirements [12]. First-year students selected a concept and developed a toy that met the requirements provided. Likewise, in a first-year course where one of the aims is to introduce the engineering design process, students are not responsible for framing the problem [13]. Instead, they were given requirements, including an arbitrary one for changing the cross-section to "increase the complexity of designs," and design is treated as beginning after requirements are set, solving deductively "based solely on simple modeling equations and the explicit loading and size requirements. "

There are a few examples in which first-year students are responsible for setting requirements. For instance, first-year students abductively developed requirements in a service-learning project to create planters for the community through benchmarking existing solutions and communicating with stakeholders and the instructor [14]. Similarly, in another first-year service-learning course, students defined problems through interactions with stakeholders—elementary school teachers and students, including many with disabilities [15]. The projects, and therefore problems they solved, were varied, including a fidget chair as well as a lesson plan, among others; this points to an ill-structured design process. These examples highlight the potential of supporting first-year students to set requirements as part of framing engineering problems. Yet, they offer limited insight into the actual processes through which this occurs. The current study addresses this gap.

Methodology

Study design

We used design-based research (DBR) study, a methodology developed in the learning sciences that jointly develops and studies a learning design while also testing a theory of learning in the form of conjectures [16, 17]. This approach relies on instantiating theory into a design and testing under real-world conditions, iteratively, with careful analysis of learning processes, learner participation, and how these relate to learning and development. Typically, DBR scholars make conjectures about how specific designs produce certain types of learning participation and, in turn, how such participation supports learning as well as related development, such as increases in self-efficacy or sense of belonging [18, 19]. In the current study, we conjectured that scaffolding the design process with a focus on developing engineering requirements can support novice designers in determining necessary requirements. To this end, we used our conjecture to guide the design of the course and course activities, including giving students guidance on how to consider requirements (and what considerations might lead to requirements) and then several opportunities to develop and revise their requirements. As instructors, the design of the course allows for the investigation of our conjecture and provides insight into both the larger research base and potential changes to future iterations of this particular course.

Participants & setting

Following IRB approval, we sought student consent to participate in the study (N = 18 provided individual consent, and three teams consented to video recording). The course took place at a Hispanic-serving R1 university in the southwest. Teams included between four and five students formed through the CatMe software [20]; we emphasized not isolating students from minoritized racial, ethnic, and gender groups, as well as matching compatible out-of-class schedules. The class included two women. In terms of race/ethnicity, the class included 10 Latiné/Hispanic students, one Native student, two Black students, and two Asian students. Seven of the students also identified at least part of their race as white.

Course activities to support requirements setting

The eight-week engineering design project prompted teams to identify a water resilience problem in New Mexico, to set ERs using research and stakeholder data, to refine ERs based on low-fidelity prototypes and scientific and mathematical models, and to use ERs to evaluate their conceptual designs (Table 1). Deliverables were due the night prior to class.

Table 1: Deliverables and course activities related to the design challenge. Highlighting and brackets indicate data collection for this study.

Week	In-class activities and deliverables
1	**In class:** Introduction to the design challenge Students generate ideas about the problem, what they want to know, and how they will learn. Information literacy & avoiding plagiarism
2	**Due**: Survey for team formation Deliverable 1: [completed individually]. Students identify a problem/need associated with ensuring water capacity for the growth of New Mexico that relates to their professional interests **In class:** Multidisciplinary perspectives
3	**Due**: Deliverable 2: Team Charter & Problem Statement / initial team problem framing **In class:** Requirements setting [Video recorded]
4	**Due**: Deliverable 3: Frame the problem based on research, propose draft requirements; prepare questions for stakeholders **In class**: Stakeholder analysis; Stakeholders visit the class. Ideation [Video recorded]
5	**Due**: Deliverable 4: Stakeholder analysis, revise requirements, evaluate solution ideas **In class**: Low fidelity prototyping, Planning prototype testing
6	**Due**: Deliverable 5: Prototype testing plan & mathematical modeling **In class**: Testing prototypes, Analysis; poster design
7	***Due***: Deliverable 6: Analysis & draft poster ***In class***: Gallery walk & peer review
8	***Due***: Deliverable 7: Final Design: Communicate the problem and your solution to a general audience; Technical poster

Data collection & analysis

Data included team deliverables, individual student work, and video and audio recordings of team interactions and whole-class instruction. We transcribed the recordings using Descript software and then corrected this automated transcript. Descript includes filler (uhs, ums) and often correctly transcribes words as spoken (“gonna” rather than “going to”) but does not correctly transcribe cross-talk and technical terms, and it tends to follow grammar rules rather than using punctuation to denote speech as delivered. We analyzed data using concept coding [21] and discourse analysis focused on agency [9, 22, 23].

Results & Discussion

We first describe the initial framing and design solutions each team proposed. We then address the research questions, interpreting the data guided by each question.

Team 1

Team 1 selected flash flooding in Ruidoso, New Mexico, as the focus of their project and proposed to develop a system to divert floodwaters away from the city. At the beginning of the project, they discovered that flash flooding during monsoon season is exacerbated by inadequate infrastructure, such as drainage systems, and primarily affects rural areas. Then, they narrowed the problem to Ruidoso and identified the citizens, the city's Mayor, and farmers as the primary stakeholders. To address the flooding in Ruidoso, they devised three ideas: diverting water to another body of water, strengthening housing materials, and using bioretention cells to manage flooding away from populated areas. Based on their defined requirements, they prioritized water diversion. By the end of the project, they constructed a simple physical model of Ruidoso to understand its geography better, planned the water's trajectory, and calculated the energy needed to pump water over hilly terrain to Mescalero Lake.

Team 2

Team 2 selected flash flooding and water pooling in the northeastern region of Roswell, New Mexico, as the focus of their project and proposed the use of permeable concrete for roads. Like Team 1, they identified heavy rains as a major issue in New Mexico, particularly for residents in low-lying areas or near water sources. Team 2 identified almost the same stakeholders as Team 1 but focused on Roswell instead of Ruidoso. The team devised two ideas to address flash flooding and water pooling: replacing traditional road materials with permeable pavement and improving existing drainage infrastructure. They concentrated on permeable pavement and further developed this idea by testing various materials for their water absorption properties. Finally, they calculated how much permeable concrete would be needed to address flooding in the lowest-lying areas inside Roswell.

Team 3

Team 3 selected the lack of drinkable water in Navajo communities caused by uranium contamination from local mining as the focus of their project and proposed developing portable systems to purify uranium-contaminated water. Since the beginning of the project, their efforts centered on Navajo communities and their limited access to clean water. Through their research, they identified uranium as one of the most dangerous contaminants due to local mining. They described key stakeholders, including the Navajo government, residents, environmental groups, and health organizations. They proposed two solutions: Building a water treatment plant to remove uranium and other contaminants or using a novel mineral to absorb uranium from water sources. They refined their solutions by testing different filtration configurations and estimating water purification rates. Based on the results, they finally envisioned a portable filtration system for Navajo families capable of removing uranium and other contaminants effectively.

How did the students use their agency in setting requirements?

Broadly, teams displayed framing agency, which is characterized by the use of abundant tentative talk, including modal verbs that express possibility (e.g., might, can, could) and limited use of modal verbs of obligation paired with first-person pronouns ("I must," "We have to"). Teams remained tentative during the initial weeks, often suggesting ideas about the problem, requirements, or solutions before discarding or modifying them. We share excerpts of team discussions during their first day of focusing on requirements.

Team 1 decided to focus on flooding, though they did not have a specific community in mind at this point in the process. Thus, they kept their discussion of requirements general and considered potentials that could apply to flooding concerns and solutions that could apply to many communities. Figure 1 shows their conversation centering on requirements related to funding and infrastructure beginning 42 minutes into the session.

Daniel: What makes it sure that we have enough funding to put it in now?
Jonas: That's true
Daniel: That might be a potential issue, is lobbying to get funding to actually implement. Systems that allow us to, yeah-
Jonas: Yeah
Daniel: But it's just like, right now we just don't have the data on a lot of the things that would cause it to fail. Like we don't have the amount of like cubic feet per second of water that's flooding in certain areas or the pure cost of like a design and //
Jonas: Yeah, like, and-
Daniel: //an implementation across like a larger scale city or something like that. Like we just don't have the numbers that we would need to implement that. ((.))
Dominic: But then 'cause like how ideal do we want our solution to be -
Evan: Yeah, because for example -
Jonas: We were saying was an ((inaudible))
Dominic: Because, for example, that would take taking up all the concrete and putting new ones in.
Evan: Right, so it would be reconstruction, basically.
Dominic: Yeah, um, But maybe they'd need that or something. Like, maybe like, whenever they build new roads, they just put new concrete use it to make a new road.
Daniel: Right, instead of like, actually us - reconstruction, we could just finish construction on, on that and then worry about remaking the other road. ((.))
Dominic: There's, there's a lake. Maybe we could divert it there or something. It's collected from the rain water and go.

High agency marker. First person singular subject
Shared agency marker. First person plural subject
Framing agency marker. Verbs show potential control
Low agency marker. External person/object subject
Low agency marker. Verb indicates lack of control

Figure 1: Team 1's talk during their initial discussion of requirements, with color coding to draw attention to how they use, share, and distribute their agency in framing the problem.

This discussion is characterized by both its tentativeness, with abundant use of modal verbs showing possibility and potential control, but also some caution, marked by lower agency construction using modal verbs of obligation. The students consistently share their agency through common use of the first person plural pronoun, "we," and by referencing the community, problem context, and stakeholders ("they," "it").

Daniel and Jonas discussed the difficulty of identifying requirements without adequate information on the community and its needs. They also attributed agency to the context ("they'd need that"), a practice experienced designers use as they negotiate their own agency with the agency of the stakeholders and situation. As the team identified the need for funding, they remained tentative, with Daniel saying, “it might be a potential issue” suggesting lobbying as a potential solution. They did not remain focused on this requirement or solution, evidence of a tentative stance in which they oscillated between problem and solution space.

Team 1 did not explicitly identify the need to implement their solution around the infrastructure in whatever community they choose; instead, they skipped to a potential solution. The team used the modals “would” and “could” to identify the choices they themselves and the community, respectively, could make as part of a solution using roads to divert flooding from the community. A consideration of integrating a flood management system into the road work that the community needs to do highlights stakeholder needs while remaining tentative about how the potential solution would work in practice. This embeds the stakeholders’ needs, as the community may want to add a flood solution to ongoing work rather than creating an additional project. Thus, this team oscillated between possible solutions and the problem as they identified requirements.

In Team 2, their conversation is characterized by tentativeness, with the use of modal verbs showing possibility and potential control, as well as speculative distribution of agency with the community, problem context, and stakeholders (“they,” “it”) and the team’s beliefs about their needs, marked by modal verbs of obligation. The students consistently own their own ideas through the common use of the first-person singular pronoun, “I.”

Team 2, by the time of this session, had identified neither a specific problem nor community. Thus, their requirements were more general than Team 1. They offered conceptual requirements, funding, and the look of the solution. They identified a potential way to fund a solution at the community level as well as the community's desire not to have an ugly solution, making a requirement for their solution to be visually appealing, as seen in Figure 2, which is 43 minutes into the session. They remained tentative about the problem and requirement, using modal verbs of “would,” “can,” and “could be.” They distributed their agency, using modal obligation verbs when discussing how HOAs make money and how this might be a model to meet the requirement of funding a solution. While considering the requirement itself, they don’t commit to a solution, instead recognizing that this solution would reduce community agency, as an HOA forces residents to pay.

Savannah shifted the conversation to another requirement. Placing herself in the shoes of a community member allowed her to identify a requirement she would want, centering the needs of the community. She used a low agency verb to identify not meeting the requirement (if it is ugly, the community is “forced” to see it). At the same time, she remained tentative about her own experience of the requirement “I would want.” Unlike the issue of funding, where the team moved immediately to a solution, pleasing visuals remained in the requirements space.

Mariah: I would put like, community costs. If like, if they're getting money taken out so that it can fund?
Sean: Also what -What's that thing called like neighborhood - where they collect money? It's like uh, an H, H something?
Mariah: Neighborhood association?
Savannah: What is it?
Sean: Homeowner's association.
Raymond: HOA?
Sean: Yeah.
Raymond: HOA.
Sean: It could be that. That's how they get money.
Savannah: A HOA?
Raymond: Yeah.
Sean: Don't they make you pay to stay there?
Savannah: Yeah. You have to pay like a fee or something. And also, like, for the community, I would want it to be, like, like visually appealing, but not, like, this big, ugly thing that, like, you're forced to see.
Sean: Yeah, that's what I meant by quality.
Savannah: Yeah
Sean: I just couldn't say that.

Figure 2: Team 2's talk during their initial discussion of requirements, with color coding as defined in Figure 1.

Team 3's talk is characterized by the distribution of agency with the community, problem context, and stakeholders ("they," "it") and the team's beliefs about their needs, with fewer modal verbs overall. Team 3 quickly moved from the problem of water contaminants quickly to a solution of a tank to clean and then hold the treated water. As part of their discussion of the solution, they moved to a requirement, clarifying more about the problem only after the solution, as seen in Figure 3, which is 19 minutes into their discussion.

Team 3, distributed their agency onto the community, generally using a matter-of-fact stance. David introduced some tentativeness to this in saying the community "can still go up," a verb that shows possibility. Paul situated the animals as having no agency, with an implicit requirement of preventing animals from entering the envisioned tank. This indicates an instantiation in the social context of the problem, not only considering how the community might use a potential solution but also situating the community as potential actors that contrast with the animals that make up part of the problem.

Despite the lack of modality in their discussions of the problem (though there are also no low agency markers to indicate lack of agency on their part), Team 3 showed tentativeness in their discussions, much like the other teams, through discussion of multiple aspects of the problem space without defining any particular aspect of the problem or solution.

Across these interactions, the teams discussed multiple topics without making firm decisions, and they oscillated between solution and problem spaces, much like experienced designers.

David: Cause I was also thinking like, a two (inaudible) system? like a small and a large kind of like, like modern cars with their turbochargers in them. There's one big one with electronics and then one smaller one using like gravity to, like, Gravity to funnel it, like, almost like a mechanism, like how electricity works. There was no electricity, so it does, like, the power drain and the whole system collapse? They can still go up to and go, pull the lever, and they still get water! Yeah, So that is that.
Dr. R: Yeah, like one more manual mechanical system and another one with more, control?
David: Yeah, control
Dr. R: Interesting
David: The only problem is wildlife. Wildlife - always (inaudible)
Dr. R: Wildlife?
David: The animals.
Santiago: Raccoons
Paul: Well, if it's contained and they can't get into it, like if it's like sturdy container.
David: Yeah that's what, what I was thinking.
Aiden: A hole?
Paul: Like depending on -
David: Like a dam kind of? Like as it comes down, it kind of filters out. And then. Like a hole? But then I was thinking, like, Oh, what if a cow just walks over and just? Now we have -
Dr. R: So they probably would want some protection to ensure that, like, both we preserve wildlife, but also protect the quality of water.

Figure 3: Team 3's talk during their initial discussion of requirements, with color coding as defined in Figure 1.

To what extent were their ERs traceable to stakeholder needs? (support validation)

Professional engineers identify stakeholders' needs and translate them into engineering requirements, a process that supports validation. In weeks three and four of the design project, students were asked to characterize the needs of the primary stakeholders and set the engineering requirements. All teams identified residents and government officials as key stakeholders but contextualized these groups within their specific project scopes. For example, Team 1 identified farmers in Ruidoso as critical stakeholders, noting: "Due to both wildfires and flooding, it has been difficult for land to both recover and be suitable for growth of crops according to wildlife officials." Similarly, Team 3 recognized the Navajo government and Supreme Court as stakeholders, stating that they "have water rights issues that prevent uncertainty of who can access which sources of water on the Navajo reservations." Rather than relying on generalized descriptions of stakeholder roles, both teams provided detailed, context-specific insights, incorporating factors such as recent wildfires in Ruidoso and the unique governance structures of Navajo communities. They center the social aspects of their problems in the requirements, such as Team 1, who considered community interest in visually appealing solutions (Figure 1), or Team 2, who considered how the cost might impact the community.

The teams developed their engineering requirements according to the identified stakeholder needs and additional information. Each team translated its stakeholders' needs into specific engineering requirements. For instance, Team 3 noted that Navajo families have an average annual income of approximately $33,000, meaning they cannot afford expensive solutions to get clean water. Thus, they defined the engineering requirement that the "solution must be cost-effective and affordable to the low-income residents." In addition to specific stakeholders' needs, the teams also defined requirements based on their literature search. For example, Team 2 incorporated insights from their literature review on flood control regulations, establishing the requirement that: "The solution complies with stormwater practices and Flood control agencies (FEMA)."

Beyond stakeholder needs and evidence-based inputs, some teams also stated requirements based on their personal design priorities. For instance, Team 2 emphasized that "the solution must be visually pleasing to the area," a requirement that the students consider relevant even though it was not directly tied to stakeholder input or their literature search. Proposing engineering requirements based on identified evidence and using their reflections as designers fosters a comprehensive approach to engineering design. Often, engineering students prioritize technical requirements while overlooking social, political, and aesthetical constraints, as well as their agency as designers [24]. Sustaining this holistic perspective is essential for developing well-rounded engineering professionals who are capable of abductive reasoning that implicitly draws from varied sources of information.

To what extent did the ERs describe what the solution should embody, not how to do it? (solution independence)

Engineering requirements connect the problem with the solution by explicitly linking stakeholders' needs with what the solution should embody without specifying it. However, it was challenging for the students to balance using only what the solution should embody instead of how to do it. Some teams identified solutions rather than requirements, which was true in their draft and refined versions. Namely, Teams 1 and 3 jumped to solutions early in the conversation rather than remaining focused on the problem and requirements (Figures 1 and 3, respectively.) In both cases, teams started at a solution and used that solution to determine the first part of the problem, then a solution that came from that problem. This is particularly clear for Team 3, who first proposed a solution to the problem, even before articulating the problem. They then used the problem to identify a requirement. This would seem to suggest that the requirements lacked solution independence because the requirement was derived directly from a solution. However, these initial solutions were tentative and differed from the final designs the teams proposed, while the requirement remained, suggesting solution independence.

After the teams' early discussion on their projects' engineering requirements, they mostly focused on defining requirements without a specific solution in the written deliverables. Although Teams 2 and 3 concentrated on establishing what any successful solution should have, Team 1 described specific solutions mixed with requirements. For instance, when identifying possible technical requirements to handle flooding in Ruidoso in Deliverable 3, Team 1 noted: "A water treatment plant will be needed as well as permeable concrete and infrastructure for the drainage systems." In this initial description, they presented three possible solutions to different problems associated with flooding. Instead of mentioning a water treatment plant, they could have mentioned the need for a system that removes a specific pollutant.

Mixing specific solutions continued in the later deliverables. For example, in Deliverable 4, Team 1 stated as a requirement that "the solution requires us to construct a better infrastructure for diverting the water into Mescalero Lake. We could construct a concrete arroyo where the water will use to travel to Mescalero Lake." In contrast, Teams 2 and 3 described factors they must consider to promote a successful solution. For instance, Team 2 said in Deliverable 3: "In terms of effectiveness, we need to be aware that since this is a water infrastructure, we must consider erosion, pressure, leak, and existing environmental factors in whatever area we're working in." Teams struggled to distinguish between requirement and solution, even as they did identify requirements, however, through the scaffolding of deliverables, they more consistently identified requirements as compared to the initial conversations.

Conclusions & Implications

Overall, scaffolding students to consider ERs in multiple ways helped them more expansively identify possible ERs. While faculty often provide ERs to students, even in capstone design, we have shown that students can and do determine requirements for the problems they have framed. During this process, students remained tentative in their talk, even when using the problem space or the solution space to contextualize the requirements. This is in line with expert designers, who oscillate between problem and solution spaces [25, 26]. Our finding that first-year students also engage in oscillatory exploration can be helpful for instructors who can further shape such oscillations into sets of requirements that have solution independence and support validation of design solutions. For instance, instructors can describe this process explicitly for students, or offer representations that help them stay aware of their navigation of problem and solution spaces, in line with recent work on building design awareness [27].

We also found that students also drew from many sources during their problem framing and requirement setting, considering social, economic, and technical factors. We prompted this in scaffolded assignments and through engagement with a stakeholder panel. However, we also note that early in students' discussions, they drew upon their everyday experiences, which supported entry into the design problems. This aligns with approaches that identify and activate students everyday and cultural experiences as resources for learning [28-30]. Instructors can support this by explicitly encouraging students to consider their own perspectives and how they might be similar to or different from stakeholders' perspectives.

One key limitation of this work is tied to the unusually high number of instructors involved in the course. While common in design-based research, where close observation is helpful for understanding the conditions under which a learning design functions, it is not a reasonable expectation to have multiple instructors in such a course. Having so many instructors sometimes limited team conversations. Future iterations will address this.

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