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Board 285: Exploring Impacts of Socially Engaged Engineering Training: What Do Students' Attend to in Scenario-Based Interviews?

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Introduction & Background

This work is situated from the perspective that engineering is a sociotechnical endeavor. The literature is inconsistent in defining what it means to be sociotechnical–e.g., engineering is sociotechnical because of the societal impacts of engineering work or because of collaborative and interpersonal nature of engineering work—[1]. Despite this inconsistency, the spectrum of social aspects has been framed by many as outside the purview of engineering practice [2]–[4].

One implication of framing anything "social" as "outside of engineering" is an underemphasis or complete lack of attention to social aspects in engineering coursework [4]–[6]. This framing is perpetuated over time in the form of engineering instructors' who may struggle to incorporate social aspects into their engineering curricula because of their own training emphasizing a solely technical approach. Structural barriers may contribute to resistance in incorporating social aspects, as well. For example, the additional time it would take to develop course content may serve as a barrier [7], especially when instructors are not rewarded for such work. Another related implication of this "outside of engineering" framing is that students struggle to include social considerations in their approaches [8], [9], even when they recognize the importance of such considerations e.g., [10]. Research suggests engineering students are even trained out of thinking about public welfare [11].

A focus on developing socially engaged engineering skills—the ability to include stakeholders, attend to the broader context, and thoughtfully consider one's individual identities, power, and motivations during decision-making in order to address complex challenges [12], [13]–is particularly important given the potential for engineering solutions to perpetuate social injustices [14] or produce disastrous consequences [15]. One tool that seeks to support instructors and engineering students in their development of socially engaged engineering skills is the Social Engagement Toolkit (SET) developed by the Center for Socially Engaged Design (C-SED) at the University of Michigan [16]–[18]. The SET is a collection of resources that was specifically designed to enable instructors, especially those who do not have training in socially engaged engineering, to integrate this content in their courses.

The SET needs to be evaluated in order to understand its impact on engineering students' socially engaged engineering skills. Thus, a pre/post study design where the SET is treated as the intervention would support an empirical understanding of how students' socially engaged engineering skills are (un)affected by exposure to the SET. Furthermore, scenario-based methods have been leveraged to assess a variety of skills and knowledge relevant to engineering, including socio-technical thinking [19], understanding of complexity [20], and knowledge of broader context [21]. A key characteristic of scenario-based methods is their approximation of real-world problems [19], while a challenge posed by scenarios is the way information in the scenario is likely to shape participant responses akin to the ways problem-framing can impact designers' approaches [22].

Research Methods

Study Goals. This exploratory study is part of a larger research study that aims to evaluate the impact of SET trainings in part by analyzing what engineering students attend to in a set of engineering scenarios, in particular focusing on participants' thinking related to socially engaged aspects of engineering. In this study we sought to explore the extent to which our pre/post scenario-based study would enable us to address the following research question: How does what individual engineering students attend to vary from prior to receiving SET training to after? We focused on analyzing participants' attention to people and context, two pillars of socially engaged design [12], [13].

Participants. Participants were recruited from public institution in the Midwest. We advertised our study to students in a mechanical engineering required capstone course by having instructors share our recruitment message with students via the university's learning management systems, Canvas. The recruitment message included a brief participant information questionnaire for interested students. We limited recruitment for our exploratory study to a single course to ensure participants had experienced the same SET training and thereby simplify the number of factors influencing shifts in what participants attend to. Our exploratory study consisted of five upper-level mechanical engineering students. The number of participants is in alignment with recommendations for qualitative exploratory studies [23], [24].

Data Collection. We leverage a pre/post study design in which participants were interviewed at the beginning and end of their semester-long capstone course. Semi-structured interviews were used in combination with a pair of engineering scenarios in both the pre-SET and post-SET interviews. Pre-SET means prior to taking a class that involved SET training and post-SET means after taking a class that involved SET training. It is possible students may have experienced SET or other non-SET socially engaged content prior to or during the semester but we did not collect that information.

The SET content covered in the capstone course consisted of self-directed online modules that covered the following content: a variety of design processes, problem definition, concept exploration, identity and power in engineering design, environmental context assessment, social context assessment, and ethical decision making. Each of these online modules consisted of five distinct sections: an introduction to the module, followed by a prior knowledge review, the core content, a knowledge check, an application task, and then a reflection activity. For more information about the structure of the learning block modules see [16], [25].

Each interview consisted of two engineering scenarios such that participants engaged with a total of four distinct scenarios. Within each interview the scenarios were presented sequentially. Participants were first shown a problem statement that included information on the background, goal, and requirements for the problem. After reviewing the problem statement, they were asked a series of questions broadly centered around gauging participants initial impressions of the problem, how they would approach the problem, and what they would need to pay particular attention to. Participants were then presented with a proposed solution to the problem and were

asked several questions aimed at gathering participants' critiques of the solution and problem-solving process that produced that solution.

To provide a variety of aspects covered by the scenarios, each interview had one scenario focused on medical or biomechancial devices and one scenario focused on energy and environmental projects. The goal used in each engineering scenario is presented in Table 1 to provide brief insight into each of the scenarios.

Table 1: Summary of Engineering Scenarios

Scenario Focus	Scenario Name	Scenario Goal
Medical or Biomechanical Devices	Motorized Scooter for Teenagers	Design a "cool motorized scooter" unlike current mobility aids for individuals with physical limitations.
	Performing Arts Wheelchair	Enhance current designs to create a wheelchair which prioritizes performers and their needs within the context of their production in order to open doors to give our customers their own stage.
	Spinal Decompression System	Design a spinal decompression system that applies a separation force to the spine to allow the disc to slip back into place
Energy or Environmental Projects	Underwater Autonomous Un-Rolling Mat	Design a way to autonomously unroll a microbial fuel cell (MFC) mat on the ocean floor.
	Water Desalination Tray	Design a device that makes saltwater potable, or drinkable, by using nothing but the power of the sun.
	Wave Energy Convertor	The objective is to design and fabricate a Wave Energy Convertor (WEC) that will be sold to power companies to install at homes and marinas.

The presentation order of engineering scenarios used in both the pre- and post-SET interviews are summarized by participant in Table 2. The scenarios selected for use in our study and the interview protocol were developed through multiple rounds of iteration and piloting, described further in our team's prior work [17].

Table 2: Summary of Scenario Ordering in Pre-SET and Post-SET Interviews by Participant

Participant	Scenarios			
	PRE		**POST**	
A	E - Underwater Autonomous Un-Rolling Mat	M - Spinal Decompression System	M - Performing Arts Wheelchair	E - Water Desalination Tray
B	E - Underwater Autonomous Un-Rolling Mat	M - Motorized Scooter for Teenagers	E - Water Desalination Tray	M - Spinal Decompression System
C	E - Water Desalination Tray	M - Spinal Decompression System	M - Motorized Scooter for Teenagers	E - Wave Energy Convertor
D	M - Spinal Decompression System	E - Wave Energy Convertor	E- Water Desalination Tray	M - Motorized Scooter for Teenagers
E	M - Motorized Scooter for Teenagers	E- Wave Energy Convertor	E - Underwater Autonomous Un-Rolling Mat	M - Performing Arts Wheelchair

Key: "E -" indicates a scenario was focused on an energy or environmental projects; "M -" indicates a scenario was focused on a medical or biomechanical devices

Data Analysis. One researcher individually read each interview and wrote memos summarizing participants' attention to various aspects of an engineering problem and solution. For the analysis presented in this paper, we focused on (1) people-related aspects, (2) contextual aspects, and (3) shifts in participant considerations between and post interviews. We were focused on attention to people-related and contextual aspects for each scenario, but we also noted when participants were mentioned these aspects: either during the presentation of the problem or their critique of the solution. Conversations with the research team supported iterative development of the coding scheme. People-related aspects included 12 codes covering attention to things such as the person or organization that provided the design task and usefulness of the solution for the end-user. Contextual aspects included seven codes covering attention to things such as the geographical location where a solution is implemented, any laws are regulations affecting the problem or solution, and impacts on the environment. The memos were further summarized in an Excel sheet so that all five cases could easily be compared. These comparisons were then used to determine the presentation order of participant cases from those that have less attention to context and/or people to those and have more attention to context and/or people. In our analysis we operationalized "attention" to people-related or contextual aspects as any time participants discussed, spoke about, or mentioned these aspects when responding to interview questions about a scenario problem or proposed solution. In this use, "attention" does not capture the quality of participants' discussion of people-related or contextual aspects.

Findings

This section presents five cases of the contextual and people-related aspects participants attended to in their pre-SET and post-SET interviews. These cases illustrate variation in the ways participant attention to different aspects shifted from their pre-SET to post-SET interview.

Table 3 provides summaries of the extent of participants' discussions of people-related and contextual aspects. Examples of increased discussions are preceded by a "(↑)," examples of decreased discussions of preceded by a "(↓)," and examples of no changes in terms of how many scenarios a participant mentioned a particular aspect are preceded by a "(—)." The ordering of the cases is from those cases with the most shifts from pre-SET to post-SET at the top to those cases with the least shifts at the bottom.

While we analyzed participant interviews by different types of contexts, the data were not rich enough to comment holistically on contextual aspects at the same the level of detail as people-related aspects. Thus, changes in contextual aspects were grouped together, while changes in people-related aspects were broken down into different types of considerations.

Table 3: Summary of Pre-SET to Post-SET Shifts in Contextual and People-Related Aspects

	Participant		Pre-SET to Post-SET Shifts in Contextual and People-Related Aspects
← Less change from pre- to post-SET interview More change from pre- to post-SET interview →	A	Context	(↑) Participant A shifted from only mentioning contextual aspects during one portion of the analysis (problem or solution) for both the scenarios in his pre-SET interview to mentioning contextual aspects during one portion of the analysis for one scenario in the post-SET interview and discussing one contextual aspect across analysis sections in the other post-SET interview scenario.
		People	He only discussed people-related aspects during one portion of the analysis for one scenario in both his pre-SET and post-SET interviews. (↓) Participant A described going to a project initiator for both scenarios in his pre-SET interview and one of the scenarios in his post-SET interview. (↓) Participant A only explicitly described going to experts for one scenario in his pre-SET interview. (↑) He only mentioned that he would meet with a variety of end-users for one scenario in his post-SET interview. (↓) Participant A talked about solution effectiveness in ways that included people for both of the scenarios in his pre-SET interview and one scenario in his post-SET interview. (—) He mentioned safety in all scenarios in his pre-SET and post-SET interviews.
	C	Context	(↑) Participant C increased discussions of contextual considerations from not mentioning any contextual aspects in his pre-SET interview to including contextual aspects in his discussions of one of the two scenarios in his post interview. Contextual concepts were mentioned across the problem and solution portions of the post-SET interview.
		People	He shifted from only discussing people-related aspects during one portion of the analysis for one scenario in his pre-SET interviews to discussing people-related aspects across the problem and solution portions of the post-SET interview. (↓) Participant C mentioned he would go to a project initiator for guidance in both scenarios in his pre-SET interview and one scenario in his post-SET interview. (—) He mentioned he would go to experts in one scenario each in his pre-SET and post-SET interviews. (↑) Participant C only mentioned talking with a wide range of stakeholders in one scenario in his post-SET interview. (↑) Similarly, he only mentioned people in his description of success for one scenario in his post-SET interview.
	B	Context	(↑) Participant B shifted from speaking about a couple contextual aspects in one of the scenarios in her pre-SET interview to mentioning several contextual aspects for both of the scenarios in her post-SET interview. Contextual concepts were mentioned across the problem and solution portions of the interviews.
		People	She discussed people-related aspects during both portions of the analysis (problem and solution) in her pre-SET and post-SET interviews. (↓) Participant B described going to a project initiator for both scenarios in her pre-SET interview, but neither of the scenarios in her post interview. Although she did not describe specifics of her research approach in her post-SET interview. (↑) She talked about project success in terms of balancing technical requirements and people considerations for one scenario in her pre-SET interview and both scenarios in her post-SET interview. (↓) Participant B talked about safety for both scenarios in her pre-SET interview and one in her post-SET interview.
	D	Context	(↓) Participant D shifted from discussing multiple contextual aspects across analysis sections in both scenarios in their pre-SET interview to discussing multiple contextual aspects across analysis sections for one scenario in their post-SET interview. For the other scenario in their post-SET interview, they only discussed a single contextual aspect when discussing the solution.
		People	They discussed people-related aspects during both portions of the analysis (problem and solution) in her pre-SET and post-SET interviews. (↑) Participant D only mentioned that they would talk project initiators for one scenario in their post-SET interview. (↑) They only mentioned that they would talk with an end-user directly for one scenario in their post-SET interview. (—) They talked about solution effectiveness in ways that included people in all scenarios in their pre-SET and post-SET interviews. (—) Participant D only mentioned safety when discussing the scenarios related to a medical or biomechanical context in their pre-SET and post-SET interviews.
	E	Context	(↑) Participant E shifted from only mentioning contextual aspects during one portion of the analysis (problem or solution) for both the scenarios in her pre-SET interview to mentioning contextual aspects across analysis sections in their post-SET interview scenarios.
		People	She discussed people-related aspects during both portions of the analysis (problem and solution) in her pre- and post-SET interviews. (—) Participant E mentioned she would talk with project initiators for one scenario in each of her interviews. (—) She mentioned gathering info from various stakeholders for one scenario in each of her interviews. (↓) She talked about solution effectiveness in ways that included people in both scenarios in her pre-SET interview and one scenario in her post-SET interview.

Participant A. *Contextual Aspects*. Participant A spoke about contextual aspects across each scenario he was presented with in both his pre-SET and post-SET interviews. However, for most of the scenarios—both in the pre-SET interview and one in the post-SET interview—he only discussed contextual aspects in one portion of the analysis, either when talking about the problem or when talking about the solution. In addition, Participant A tended to mention only one type of contextual aspect. For example, when talking through the challenge of making theater more accessible for actors who require a wheelchair for mobility in his post-SET interview, he focused on features of location where the solution would be used, saying it would be important to pay attention to:

> *The size of the wheelchair and focusing on the way it can overcome some challenges in backstage areas like that are not as easily wheelchair accessible. Yeah, I guess finding common obstacles in these backstage areas and then working backwards to see what this wheelchair can offer to overcome those obstacles that these performers are encountering.*

When critiquing the presented solution, Participant A suggested the team could have "made [the wheels] larger to pass over larger bumps that could be in the ground."

People-Related Aspects. Across three scenarios—both scenarios in the pre-SET interview and one in the post-SET interview—Participant A focused on gathering information from the organization that had provided the problem, professionals, or experts in the field. However, for one scenario in his post-SET interview—the performing arts wheelchair—Participant A stated he would try to meet with a variety of end-users. When responding to a question about what he would want to make sure he addressed in the provided problem statement, Participant A stated that he would want to make sure to "try to meet with as many performers that are in wheelchairs as possible, to work with them, to sort out what requirements are necessary for this device." Participant A provided detail on how he would engage with performers when describing how he would approach this problem, saying:

> *I would reach out to performers that are in wheelchairs and I would conduct interviews with each individual or as many as I could. Then I would form maybe a list of questions or kind of like a Likert scale of things that the performers find least valuable or most valuable for the wheelchair that the team would design and prototype and make... I think like working with the, that stakeholder in the project could be valuable since each performer would've their own kind of thing.*

During his pre-SET interview, Participant A talked about stakeholder satisfaction, albeit vaguely, for the autonomous un-rolling mat saying: "I think if it meets all the requirements and the intents of the organization and the different stakeholders and stuff, then I think it would be a success." In addition, he included impacts on end-users when describing an effective solution to the spinal decompression problem in his pre-SET interview, stating:

> *I think it would be effective if it meets all the requirements and also, yeah, if it meets all the requirements and also helps people in the end without hurting them. So, it'll probably be a longer-term viewpoint to see how much it helps.*

In contrast, during his post-SET interview, Participant A focused on a technical confirmation of saltwater being removed for the desalination tray problem and talked about success from a market success perspective during his discussion of effective solutions for the performing arts wheelchair scenario. In other words, the more people using the product the more successful it is, stating "I would like to see, over the long term... seeing how many performers in wheelchairs actually end up using their product."

Participant A talked about safety of at least one stakeholder group across all the scenarios in the pre-SET and post-SET interviews. In the pre-SET interview, when discussing the autonomous underwater mat, he said it would be a quality product "if it meets certain safety standards for the workers... maybe there's people that have to do maintenance on it, that sort of thing, or hear work around that device." In discussing the challenge of spinal decompression during the pre-SET interview, he explained how he would work around end-user safety concerns by prototyping a spine to test on instead of testing on people. In the post-SET interview, Participant A talked about safety concerns regarding users potentially pinching themselves in the performing arts wheelchair and the safety of the water in terms of whether people can drink it after it has gone through a desalination process.

Participant C. *Contextual Aspects*. Participant C did not speak to any contextual aspects when describing his own approach to the problem or his critique to the presented solutions for both scenarios in his pre-SET interview. In his post-SET scenario, he did not mention any contextual aspects in one of the scenarios, but in the other one—focused on leveraging the power of the waves to provide renewable energy to coastal communities—remarked on where the wave energy convertor would be installed. For example, when asked about what could become an issue if it were overlooked by the engineers working on this problem, Participant C said:

> One thing is waves. There's a lot of different types of waves depending on the weather and the wind. I should say there's different types of waves in different locations on the coastline... just making sure the converters versatile from multiple types of waves. And then just the durability of it, I think is really important because if it's going to be in the ocean, then that's a really tough condition for any device to be in with salt and rough waves crashing around it.

He also asked about the systems and structures that would need to interface with the solution when responding to a question about what the team—who created the solution under critique—may have overlooked or could have done differently, saying: "Once it creates the electricity, how's it going to transport that to power company or wherever it needs to go?"

People-Related Aspects. In both of the scenarios in his pre-SET and one scenario in his post-SET interview, Participant C mentioned he would approach the scenario's problem by going to whoever had initiated or sponsored the project for guidance on next steps, clarifications of the problem, or expert information. When talking through how he would gather information about the challenge of making saltwater drinkable during his pre-SET interview, Participant C said:

> First maybe going on the internet, seeing what I can find. Then from there, trying to use my resources of who gave this problem to me. Perhaps the person who is assigning this

problem has some experience in the field, or perhaps they could direct me in a certain direction of where to find some information.

That'd be one thing is to ask, I guess, the sponsor or whatever group gave of this issue to our group. Ask them if they know any articles or of any certain places to look or any people to talk to. If there's people to talk to, set up some conversations with them to try to get more information from them and learn from their experience. Just working with who gave me and seeing what they can supply if they can supply any help as well.

In addition, he mentioned he would meet with experts or professionals in both the spinal decompression (pre-SET) and wave energy convertor (post-SET) scenario.

Participant C only explicitly mentioned that he would talk with a wide range of stakeholders for one scenario in his post-SET interview. When asked how he would approach the problem of creating a "cool motorized scooter" for a student that requires mobility assistance, he said:

I would first set up a meeting with perhaps the stakeholders. So maybe the student who needs the mobility assistance and then whoever maybe works with the student or helps them like assists throughout the day maybe, mobility stuff. And then whoever else is involved, maybe the parents or other engineers who are going to be helping design or have input on the scooter.

During his pre-SET interview, Participant C described project success as measuring a numerical outcome for the water desalination tray and in terms of people's bodies for the spinal decompression system. He discussed attention to a person's body in ways that do not necessitate attending to the person's thoughts, feelings, opinions, etc. While one description of success in their post-SET interview focused on confirming technical function, they talked about people in their other post-SET scenario in a way that considered the end-user's perspective when describing an effective solution for the motorized scooter scenario.

Participant C mentioned some concern regarding the logistics and ethics of testing a spinal decompression device during his pre-SET interview when talking through potential pitfalls of the spinal decompression project, stating:

I think some potential pitfalls, just knowing... I don't know how you would test the design would work is what I'm curious about, I guess for thinking. How you know that it would work and allow the disc to slip back into place... Because I feel like that's hard to test. Are we going to test that on a person? I don't know if that's ethical or if there's a model you can test that on. I just think that's going to be something difficult and hard for the group to confirm that the design works...

I have no idea, honestly, how I would know [if a solution was effective] besides testing it on a person, how I would know it's successful. I'm not sure really where to begin. I wouldn't really know, I guess how... I don't know how you would know. I think you would need more of a target, like decompression value or something like that.

Participant B. *Contextual Aspects.* Participant B spoke about contextual aspects in one of the scenarios she was presented with in her pre-SET interview and both scenarios in her post-SET interview. In the pre-SET interview she did not mention any contextual aspects when discussing the motorized scooter for teenagers, but focused in on features of the location where the solution would be used for the autonomous underwater mat and suggested it would be useful to know how the generated electricity would be transmitted from the solution to where it needed to go. For example, in responding to a question about things that might go wrong when addressing this problem, Participant B said:

> Then electricity, that entire aspect is also a problem, especially because it's underwater. You have to have good material so that none of it leaks and the electricity doesn't discharge into the water. And then the water itself, like I said earlier, it's kind of corrosive... And another thing is transmission, we don't have to consider it, but it would be useful to know what kind of transmission is working, how the electricity's getting delivered to the final source.

In the post-SET interview she mentioned several contextual aspects, often without going into much detail, for the challenge of making saltwater drinkable. For example, when describing how she would approach this problem, she said she would consider "all the social factors, sort of also considering where these people would live, I guess regional factors, factors in climate and all that." Participant B also talked about solving issues within "our power" when describing her approach, explaining:

> Well, this issue, or at least I'm looking at the low cost, and it's just the big issue of poverty. Well, why are they poor? Who did this? What happened? It's not something that we can really solve on our own as engineers. It's really a very wide-reaching social issue.

In addition, when prompted to talk about what sort of information she would want to gather, Participant B talked about gathering information about other contextual aspects, stating:

> Are there some kind of relevant cultural elements that would affect how we would impact the design? So examining the population, and what they would potentially want, and then going to the environmental factors, sort of what kind of work? In this particular case, definitely looking at the sunlight, solar irradiation, and maybe even salt water.

Another example of Participant B's discussion of a contextual aspect is her response to a question about what might go wrong when working on the water desalination tray: "If it becomes something more complicated and goes into the realms of politics, then that can get out of hand very fast, but that's a whole different realm."

On the other hand, when discussing spinal decompression, Participant B only discussed a contextual aspect when describing her first impression of the problem statement, saying:

> It's good to have a cost maximum, but... Well, for this particular problem, I guess it's not needed, but this goes back into society, and personally, my opinion is that healthcare should not be this costly.

People-Related Aspects. From her pre-SET interview, Participant B's information gathering approach focused on going to a project initiator. For example, when explaining her approach for the challenge of creating a "cool motorized scooter" she said:

> *Well, the main thing is talking to whoever wrote the specific goal. What do they mean? Ask questions. What do they mean by "cool"? What are they looking for? Why are they looking for this solution instead of, I don't know, this [other solution]? So basically, talking to the main person seeing what they really want.*

In her post-SET interview, Participant B did not mention going to a project initiator, but also did not mention specifics of how she would conduct research.

Participant B talked about project success as balancing technical requirements and people considerations for one of the scenarios she was presented with in her pre-SET interview and both scenarios in her post-SET interview. For example, in her pre-SET interview, when discussing the motorized scooter for teenagers, Participant B said a solution was effective "if the student is satisfied and if this device works as per its requirements." On the other hand, she focused on technical requirements for the other scenario in her pre-SET interview—the underwater autonomous un-rolling mat—describing a good solution as "addressing the goal, which is an autonomous un-rolling MFC mat on the ocean floor. A net positive electrical generation of course."

Participant B also mentioned safety for both of the scenarios she was presented with in the pre-SET interview and one scenario in her post-SET interview. In here pre-SET interview she asked if there was a safety backup for the underwater mat solution and commented on the safety components visible with the motorized scooter for teenagers solution. In Participant B's post-SET interview, she remarked that the spinal decompression solution did not look like the "safest thing, but did not mentioned safety explicitly when talking about making saltwater drinkable.

Participant D. *Contextual Aspects*. Participant D spoke about contextual aspects across all four scenarios they were presented with in their pre-SET and post-SET interviews.

For one of the scenarios in their pre-SET interview Participant D talked in detail about several contextual aspects when talking about the problem and discussed the location where a solution would be implemented when discussing both the problem and solution. For example, when discussing the scenario focusing on converting the power of waves into renewable energy, they described approaching the problem by:

> *Start[ing] with research. So probably reading in books or periodicals about or projects like this and why they decided to build it in the area they decided to build it. What characteristics of the ocean around there made it a good choice to put.*

Participant D's initial reaction to the team's work on a wave energy convertor was:

> *They have compensated for the ranges in tidal motion. So, that's something good that they've considered that some people might overlook. Let's see what else they have. The counterweight that hangs down. I'd be curious as to what they're going to make the*

counterweight out of to make sure that it doesn't get corroded or doesn't get worn down as it's just sloshing up and down in the water 24/7.

In the other scenario in the pre-SET interview, Participant D discussed a couple contextual aspects and mentioned contextual aspects when talking about the problem and solution.

For one of the scenarios in their post-SET interview, Participant D similarly discussed a couple contextual aspects and mentioned contextual aspects when talking about the problem and solution. However, for one of the scenarios in their post-SET interview they only discussed a contextual aspect when talking about the solution. In describing their initial reactions to the motorized scooter for teenagers' problem statement they commented:

> *I don't know if he's going to be traveling through doorways with this or if it's just on sidewalks, but that might be an issue. Or if it's like a crowded sidewalk, you don't want a scooter that's super wide and bashing into people's shins. Seems like they used a good size front wheel, so they shouldn't have any problems running into bumps and getting thrown of the scooter.*

People-Related Aspects. During their pre-SET interview, Participant D mentioned that they would talk with experts to understand users' bodies for the spinal decompression scenario. Rather than discussing engaging with stakeholders, Participant D voiced assumptions about stakeholder wants when discussing the wave energy convertor during their pre-SET interview.

In their post-SET interview, Participant D mentioned he would talk with the project initiators and talk to the team who had worked on the project previously for the water desalination tray scenario. Similar to their pre-SET interview, they voiced assumptions about end-users when discussing the scenario focused on creating a motorized scooter for teenagers in their post-SET interview, however, they also mentioned that they would talk with the end-user directly—with some of the conversation focused on understanding the user as a person and some focused on understanding the user as a body. They talked about approaching the problem in the following way:

> *Probably first let's find the student that they're talking about and talk with him. So probably see how much he weighs and that could further refine the weight capacity. Kind of see how tall he is and that can inform what dimensions the scooter actually needs to be. Kind of figure out how well his arms and legs work and that can help inform the storing time to figure out if it's going to be a foldable scooter, if he can activate all the parts, if he can turn the levers, if he can do all that kind of stuff. Yeah. And then also kind of figure out what the student is doing right now for getting around. Is he using a wheelchair? Is he using a different kind of electric scooter? Kind of figure out that and then see what he does and does not like about the current solution and that can kind of focus the team's efforts on fixing the things that he doesn't like.*

Participant D's descriptions of success touched upon people across all four scenarios in their pre-SET and post-SET interviews. For example, in their pre-SET interview they talked about

determining if the spinal decompression solution is effective through something like a clinical trial that blends end-users' subjective feedback with a systematic approach, explaining:

> *It seems like back pain is generally a pretty subjective measurement. The best you can usually do is just kind of interview the patient and they'll kind of describe their comfort level and how much it's hurting them. Doesn't seem like there's ... a lot of times it's kind of like a phantom back pain where like look at their back cat, scan, MRI, whatever you're doing. It's just hard to see what's wrong, but the pain is still there and it's still very real. So, I guess the best way to go about seeing this is effective is interviewing the patients before and after the treatment. Maybe even have a control group where they don't know whether or not they're actually receiving the treatment, just like they do for a lot of other medical treatments. That way you can kind of weed out any bias in the interviews... I guess you'd want to see at least say a 30, 40, 50% decrease in the pain that they're experiencing. So, I don't know. Maybe have them use one of those scales, like one to 10 that they like to do and then kind of compare the before and after pain levels. I guess it's effective if they it's reduced the pain by a certain percentage. Obviously, I don't know what an exact percentage would be, but that'd probably be a good way of going about that.*

When discussing converting the power of waves to energy in their pre-SET interview, they said there were a couple of factors to look at to gauge effectiveness. While many of these factors were associated with technical requirements, Participant D's comments on aesthetics showed concern for context and people:

> *Probably the most important is the actual energy generation... You could also measure the noise pollution that it generates... things that are kind of harder to quantify is how much it kind of obstructs the view or how much of a visual blight it is on the coastline. So those would be more subjective. You'd probably have to interview people to see what their thoughts are on the visual of these things, durability and resilience. You could probably do simulated long term tests at a lab. So spraying it with salt water or changing the temperature rapidly over time in a chamber that would help simulate its durability or resilience. You could see if the paint's wearing off or if there's defects or if it starts to not work properly. Those could be ways to test that.*

Participant D only mentioned safety when discussing the scenarios related to a medical or biomechanical context in their pre-SET and post-SET interviews. When discussing the challenge of spinal decompression in their pre-SET interview, they discussed safety in terms of the dangers of messing with the spine being overlooked by engineers when responding to a question about what they foresee becoming an issue if it were to be overlooked by the engineers attending to this problem, explaining that:

> *if they don't do enough background research and they don't quite know the dangers of messing with the spine, they could go ahead and design a solution that sure, it might apply the force that they were told it needs to apply, but there could be other factors that would damage the spine even further, since it seems like this would be a pretty delicate*

treatment. So, they don't want to push the spine too far or in the wrong direction or twist it the wrong way.

When critiquing the presented solution, they commented that:

[The] lead screw is probably too long right now. You might want to cover some of the moving parts. You might not be allowed to bring this to market if regulators deem that too dangerous. It might catch on clothing.

In responding to a question about what they think the team did well with their solution for a motorized scooter for teenagers in their post-SET interview they said "they added a kill switch. Might be overkill, but that also shows that they're thinking about safety, even if it wasn't necessarily listed."

Participant E. ***Contextual Aspects***. Participant E spoke about contextual aspects across all four scenarios she was presented with. In her pre-SET interview she mentioned several contextual aspects, without going into detail, when discussing a scenario's problem but did not mention contextual aspects when discussing the proposed solution. In her post-SET interview, she mentioned a couple contextual aspects across discussions of a scenario's problem and solution. For the underwater autonomous un-rolling mat her post-SET interview, Participant E went into detail about environmental considerations and the location where the solution would be use. For example, when talking about what information she would want to gather, she said:

I would also want to know if what I had said earlier about the ocean floor [and disturbing the environment], what my company plans are. To make sure that the ecosystem isn't getting disturbed. If they don't have any plans for that, I'd want to... I don't know. If there's some like department or whatever that I can talk to in my company to make sure that they're like on this. Making sure that this isn't doing more harm than good. They should reach out to people who study the ocean and sea life and stuff like that.

When reviewing the proposed solution for an underwater autonomous un-rolling mat during her post-SET interview and responding to a question about what the team—who made the proposed solution—may have overlooked or could have done differently, she said:

For example, in this image of the unrolling functionality, it assumes that there's just this empty area that's completely flat and there's nothing obstructing it as it's unrolling but also underneath it. I think that's a pretty bold assumption, especially if you're on the ocean floor.

People-Related Aspects. In her pre-SET interview, Participant E described her approach for the wave energy convertor as:

I would try to narrow down or understand the background more and narrow it down a lot more to see which specific communities I'm targeting, and learn more about the communities I'm targeting. Or if it's the power company that targeting, who am I specifically trying to work with.

While she mentioned trying to figure out which stakeholders she is targeting, she did not discuss stakeholder engagement more concretely.

When discussing her approach for creating a motorized scooter for teenagers in her pre-SET interview, Participant E seemed to rely on a project initiator at first but acknowledged that information gathering would expand to end-users. She described her approach as:

> *First, I would try to talk to the person who gave me the problem. So, try to clarify what their intentions were and where they were coming from when they brought me this question, this design problem. Also try to get to know their intentions as well. If they can answer those questions about the scooter and also who I'm actually designing for. Then after that I would do as much research as possible about or background research just for myself about mobility and the specific conditions that these individuals have that give them physical limitations. So, I have some understanding of them and just like mobility. Then after I have a more solid understanding about them and the problem, I can start talking to them to see if this is a problem that they actually face, what solutions they've tried in the past, what their needs are.*

In addition to talking to people who study the ocean and sea life, Participant E seemed to heavily rely on a supervisor being able to provide a lot of information regarding the underwater autonomous un-rolling mat in her post-SET interview. When she responded to a question about what type of information she would want to gather and how she would gather it, Participant E said, "I think all of those things, those should be able to be answered by my supervisor, whoever tasked me with this."

However, in her other post-SET interview scenario focused on making theater more accessible for actors who require a wheelchair for mobility she focused on gathering information from various stakeholders describing her approach as:

> *Interview stakeholders and stuff and narrow down the people that I'm targeting potentially... I'm not in a wheelchair and I'm pretty unfamiliar with that and also performing arts. So definitely, being able to observe or perform design ethnography stuff to better understand who I'm trying to design for would be really important to me.*

Participant E's descriptions of success touched upon people or context across all four scenarios in her pre-SET and post-SET interviews. In her pre-SET interview, she talked about the motorized scooter for teenagers being effective if:

> *it improves the lives of the individuals without creating additional problems for the individual, but also for key stakeholders in or the problem, maybe the individual's family or the school or the environment.*

For the wave energy convertor in her pre-SET interview, Participant E talked about how success is generally meeting requirements when requirements "reflect what the users want and reflect success of the product," and said:

it'd be a good solution if it provides clean, renewable energy to people who didn't have energy before or it's fulfilling some need without damaging other people in the process or other things in the process, like the environment or the power or just other stakeholders.

In her post-SET interview, she described success for the underwater mat as "it generates electricity from bacteria on the ocean floor without harming whatever ecosystem is there." Finally, in her post interview, Participant E described the solution to making theater more accessible for actors who require a wheelchair for mobility as effective if:

More actors who are in wheelchairs feel that they have the resources to perform if given the opportunity to or like physical resources. They feel that this wheelchair helps them perform better than existing/standard wheelchairs.

Discussion

This work investigated impacts of a Social Engagement Toolkit (SET) developed by the Center for Socially Engaged Design at the University of Michigan on the extent to which students shifted the ways they discussed people and context as important considerations in design work. We hoped to see an increase in the discussion of people and context, two pillars of socially engaged design [12], [13]. It is important to note that we did not rank the quality of the discussion of people and context, but rather focused on if participants named these aspects in their discussions of the scenarios in their pre- and post-SET interviews and if there were shifts in what they named from their pre- to their post-SET interview. As the five cases highlighted, our pre- and post-SET interviews with undergraduate mechanical engineering capstone students elicited a variety of responses about people-related and contextual aspects, and these varied by interview (pre-SET or post-SET), scenario, and analysis section.

In alignment with what we had anticipated, the types of people-related aspects and contextual aspects that were most salient varied from scenario to scenario. For example, sometimes participants who had not mentioned safety at all mentioned safety once seeing the proposed solution poster for the motorized scooter for teenagers, which had a section called "Safety Components" or the proposed solution poster for the spinal decompression systems which had a "Testing and Evaluation" section that listed multiple safety factors. We addressed this challenge by including multiple scenarios such that participants never saw the same scenario twice and randomly assigning scenario presentation order in the pre- and post-SET interviews.

In addition to the scenarios, the structure of the participants' capstone course projects—beyond the SET training—may have been an additional factor that impacted participant interview responses. The capstone course taken by our participants was structured such that many of the student teams had a single project sponsor or primary stakeholder. In this exploratory study, all five participants described going to whoever had initiated or sponsored the project for more information during at least one of their interviews. Furthermore, it is important to note that beyond the capstone course structure our study participants may have had different instructors, been situated within different teams, and leveraged SET within their capstone projects to varying degrees—all of which may have influenced the extent to which students engaged with the SET materials.

Overall, we observed changes between participants' pre- and post-SET interviews. All five participant responses showed increased discussion for some contextual and people-related aspects and decreased discussion for other contextual and people-related aspects from their pre- to their post-SET interview. Our findings for people-related aspects focused on what types of people-related aspects were discussed and when the different types of people-related aspects were discussed. On the other hand, given the lack of consistent attention to a variety of contextual aspects, our findings for contextual aspects were focused solely on the presence of discussion of contextual aspects across analysis sections rather than the types of contextual aspects discussed. While participants discussed more people-related aspects more consistently than contextual aspects, our preliminary findings suggest there is room for growth in preparing and supporting students in attending to both people-related and contextual aspects. One implication, for both instructors and researchers, of this opportunity for growth is to investigate the surrounding course and discipline to understand how other variables—beyond SET—weigh into what students attend to. Furthermore, this implies an opportunity to further refine how we are measuring participants attention to contextual and people-related aspects. For example, iterating on the ways we are probing for participants' attention to these aspects within our interview protocol.

Acknowledgements

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