Countering Passive Engagement: STS Postures and Analyzing Student Agency in Everyday Engineering

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Abstract

"A culture of disengagement" is what Erin Cech [1, see also 4,9] has named the phenomenon that, within engineering schools, students graduate with less interest in societal issues than when they arrive. Much of this disengagement is attributed to mindsets ([2]: centrality of military and corporate organizations, uncritical acceptance of authority, technical narrowness, positivism and the myth of objectivity) and ideologies ([1]: technical-social dualism, depoliticization, meritocracy) that create a socio-technical divide that encourages many students to marginalize social issues related to engineering. In recent years, some scholars have proposed ways to overcome this disengagement, for example Jon Leydens and Juan Lucena's (2018) "Engineering for Social Justice Criteria." However, little research has been conducted to trace how engineering students are taking up these programs.

This paper builds on an NSF-funded ethnographic study of cultural practices in a Science, Technology, and Society (STS) program that serves 1st and 2nd year engineering students [6, 22-23]. That research study sought to answer: How does this program cultivate engineering students' macro-ethical reasoning about science and technology? Radoff and colleagues [6] identified four salient ways that students described the cultural practices of the STS program: 1) cultivating an ethics of care, 2) making the invisible visible, 3) understanding systems from multiple perspectives, and 4) empowering students to develop moral stances as engineers in society (developing a sense of agency). This paper builds off of insights uncovered from Radoff et al by zooming in on the ways students describe how their sense of agency manifests during their time in the program. On top of interview and focus group data, we draw examples from STS student participant observations in STS courses [27]. We use examples drawn from this data to reflect on how encouraging student agency can help overcome the socio-technical divide.

Introduction

How to navigate a "culture of disengagement" within engineering education has been a pressing issue [1]. Students leaving engineering schools with less connection to societal issues related to engineering move into workplaces where understanding the societal implications of engineering is essential (e.g. adopting alternative energies, creating batteries from materials that do not rely on child labor, etc.), and failure to appreciate these implications can be catastrophic (e.g. climate change, health care disparities, or the growing dependency on artificial intelligence). This disengagement has been attributed to mindsets ([2]: centrality of military and corporate organizations, uncritical acceptance of authority, technical narrowness, positivism and the myth of objectivity) and ideologies ([1]: technical-social dualism, depoliticization, meritocracy) that create a socio-technical divide – a divide that encourages many students to marginalize social issues in the context of engineering. In general, STEM education "remains far removed from most people's lived experiences and is detached from the real-world social, political, and economic contexts in which it exists (p. 1)" [3] and students can be intentionally or unintentionally discouraged from understanding technologies from macro-ethical perspectives. When these socio-political connections are obscured, existing inequities within engineering practices may be inflamed. For example, when students from historically underrepresented groups in engineering don't see their communities' problems centered in the engineering curriculum, they are further marginalized and often transfer out of engineering majors [4]. Overcoming the socio-technical divide within STEM spaces may empower students to express

alternative forms of agency, by normalizing the formation of moral and ethical positions on science and technology issues. In recent years, scholars have proposed ways to overcome this disengagement, for example Jon Leydens and Juan Lucena's [5] "Engineering for Social Justice Criteria." However, little research has been conducted to trace how engineering students are taking up these programs.

Our research on how STS Postures influences the macro-ethical thinking of undergraduate engineering students begins to fill this void [6]. STS Postures, a framework with three interrelated and reinforcing features, is designed to create a space for students to try on a critical mindset about technology in their classes, so they may eventually take that perspective into their internships and careers [7,8]. The first feature aims to heal the modern mind/body fracture by helping students develop a sense of how bodies and emotions contribute to knowledge production and engineering design. The second feature provides students with analytical approaches grounded in STS theory (e.g., locating power, interpretive flexibility, democratization of S&T, etc.) to ask questions about their everyday encounters with engineering education and technology. The third feature consists of data collection techniques (e.g., interviews, participant observation, visual representations, etc.) that can reveal hidden relationships between society and technology. Taken together, these features encourage students to try on mindsets about science and technology that situate themselves as change agents.

In this paper, we articulate how STS postures encourage a sense of agency for challenging the status quo, both in engineering curriculum, and by extension, how professional engineers conceptualize filling the needs of communities – either their own or those communities that interface with engineering practices. This involves redefining what education means to students and how they should approach it. The existing model for engineering education is largely driven by achieving technical competency. Most engineering courses are instructor-driven and many engineering professors feel unequipped or too pressed for time to cover material that appears "non-technical" or to step outside the confines of a "banking model" of education (which will be explained in the following section). So while opportunities that exist for thinking socio-technically in engineering courses go unturned, the students who are most interested in social issues leave engineering at the highest rates [1, 9].

This paper proceeds as follows: We begin by defining what we mean by agency and situate our definition in the engineering education literature. Then we describe the STS Postures curriculum and present a model to guide the analysis of how it encourages student agency to navigate the status quo of engineering education, and by extension, their engineering careers. Next we describe the methodological origins of this paper that suggested students were taking up this curriculum in the ways it is intended [6], followed by examples from student interviews and classroom observations. And last, we discuss the implications and limitations of this analysis and potential future research.

Student Agency and Dominant Engineering Mindsets and Ideologies

Agency, as we define it, requires the ability to take standpoints from self, and others through body-based awareness practices that reveal personal biases, values, and assumptions about ourselves and the people with whom we work and socialize. Self awareness allows one to understand how their identity is simultaneously perpetuated and reconstituted through our

actions in the world [10-11]. It also helps one realize how agency is constrained and challenged by dominant cultures [12-13]. This perception of self is complemented by an understanding of the relational situatedness of the student to others or communities they work with [3, 14]. These perceptions in turn can lead to the use of tools to enact change they identify as necessary or desirable on a personal and community level. Before describing our model of STS Postures and its connection to student agency, we connect our definition of agency to the engineering education and STEM education literature more broadly.

Donna Riley's [2] observation about engineering students' mindset of willingness to help is a good foundation to build from, although this mindset is often dampened or diluted by other engineering mindsets and ideologies [1]. This reason points to why student agency as a form of resistance against and liberation from the hegemony of dominant ideologies and social structures is so commonly invoked [15]. Building off bell hooks [15] work, Secules and colleagues [13] identified a form of student agency that emerges from theorizing narratives about one's experiences encountering dominant mindsets and ideologies [1-2, 5] of an engineering program. They explored the experience of a student from a historically marginalized underrepresented group in engineering and found that "constructing and reflecting on narratives about [student] experiences and relating them to cultural narratives about engineering and STEM were central to [the student's] theorizing about [their] oppression (p. 190)" [13].

Secules and colleagues analysis situates narrative agency in two spaces simultaneously - the learning spaces of engineering schools and the ways that we make sense of and form identities within the cultural milieus we experience "growing up" in our everyday lives [10]. This rendering of student agency inspires us to prioritize pedagogy that challenges the "banking model" of education, where one person (usually the instructor) provides knowledge to the students [16]. We object to the ways this model constructs students as passive: they are expected to take up knowledge but are rarely asked to exercise their capabilities to be active co-constructors of knowledge. This model is widely adopted in engineering education and reinforced by dominant ideologies and mindsets of engineering such as technical narrowness, uncritical acceptance of authority, the myth of objectivity, depoliticization, meritocracy, and technical-social dualism [1-2].

Similarly, Imad and colleagues [3] outlined three "agreements" commonly found in Euro-American STEM education more broadly; the agreement to privilege Eurocentric ways of knowing, the agreement of scarcity (e.g., there have to be winners and losers - grading on a curve), and the agreement of "objectivity" and proposed a way to catalyze student agency through humanizing STEM. This entails "intentionally and explicitly ground[ing] all of our work in our responsibility to recognize and respect the inherent worth and dignity of *all* of our students, regardless of their background and field of study (p. 2)." They prescribe an ethic of care to motivate student autonomy [17-18]. Agency is defined relationally: students are supported to understand the "situatedness" of people and non-humans in their lived experiences [14]. When agency is defined through an ethic of care, this means students can explore and determine their own responsibilities and ideas while taking into account interactions between themselves and others. Imad and colleagues propose that one step toward mobilizing change is "recasting the unspoken agreements" mentioned above by embracing multiple ways of knowing, holding a mindset of abundance (i.e., everyone can master a subject), and centering humanity and nature in the STEM curricula. We find kinship with efforts to create curriculum driven by an ethic of care

[6], and also, with the idea of "recasting agreements" [19]. We also acknowledge that engineers in training and in the workforce often encounter situations where they must make decisions or perform tasks that conflict with their personal values [20-21]. This inevitability is one we should prepare our students to navigate.

STS Postures and Student Agency

The STS Postures curriculum has been described in previous studies [6-8, 22-23], so we only briefly contextualize it here. The first two authors of this paper developed the STS Postures as a way to integrate insights from many pedagogical traditions to teach ethics and science and technology studies to STEM majors. The word "posture" connotes intellect (as in mindsets) and physicality. Three interrelated features (analytical approaches, body/mind fusion, and data collection techniques) (Figure 1) constitute tools for showing students how to recognize/uncover complexity in science and technology issues.

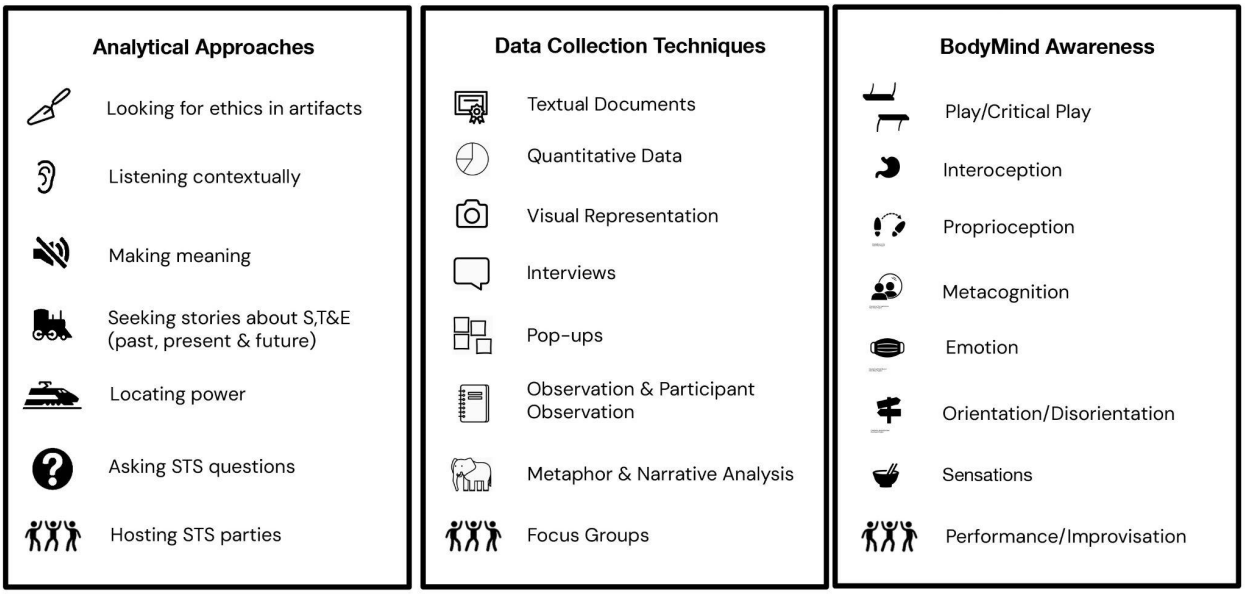

Fig. 1 - The three facets of the STS Postures curriculum: analytical approaches, body/mind skills, and data collection techniques.

We address body/mind fusion here in more detail because it requires the most explanation and because activating body/mind skills is fundamental to student agency that asks (STS) questions of the dominant engineering culture. Body/mind fusion encourages students to go beyond the traditional scientific method that relies heavily on the "myth of objectivity" and technical narrowness. We included this dimension specifically to include feminist critiques that pointed out the necessity of understanding the situatedness of science and technology [24-25]. This critique calls on us to include other ways of knowing, including subjugated knowledges and senses (e.g., emotions, hearing, smell, taste, interoception, etc.), in the development of science and technology [26]. This feature of STS Postures also helps students and instructors reconsider the banking model of education by including bodily sensations when exploring how others

(human and non-human) know things and feel things about existing and emerging science and technology. Body/mind fusion is the connective tissue that shapes the facets of analytical approaches and data collection techniques. Bringing the body, along with the mind, into class is the foundation for connecting with others through empathy, as it helps students realize that their own emotions, feelings, bodily movements, opinions, and knowledge are important for understanding how they relate to science and technology. It is a pathway toward "humanizing" and "ecologizing" engineering and a movement away from solely intellectualizing and detaching oneself (e.g., objectivity) from a problem. In other words, we are inviting students to situate themselves emotionally and physically, to conceptualize the body as a source of knowledge and also a source of bias.

Our definition of agency requires the ability to take multiple body/mind standpoints – self, and other. Resmaa Menakam's [11] work on somatic practices and interoceptive-based self-inquiry informs this way of framing agency. Interoceptive skills help us identify physical sensations in our bodies. Once we identify them, it becomes possible for us to link those physical sensations to biases, values, and assumptions. Menakam has worked with people in communities and organizations, notably with law enforcement, and this work helps people lower their own reactivity by identifying resources they can use to de-escalate violence [11]. Similarly, teaching students to connect bodily sensations to their own biases opens pathways for speaking critically about science and technology, and recognizes alternative avenues for pursuing change (and/or freely express/experiment with their identities) in their classrooms, local communities, and their lives [10, 12-13]. The starting point for nurturing this kind of agency is through an ethic of care [17], where instructors model care for others by forming deep connections with their students and a situational understanding of their lived experiences as engineering students.

As previously mentioned, our analysis of student agency is inspired by an earlier study of the culture of the STS program at the University of Maryland College Park [6]. That analysis revealed four salient ways that students talked about the STS program; It: 1) embodies an ethics of care; 2) helps make the invisible visible; 3) shows how to understand issues from a socio-technical systems view; and 4) encourages alternative expressions of student agency inside and outside the classroom. This last observation inspired us to examine student agency more closely, and led us to sketch a non-linear model that describes how we perceive the STS postures help students explore alternative ways of expressing agency (Figure 2).

This model displays three interrelated student experiences where agency is encouraged and practiced: *foundations of agency*, *practicing agency*, and *navigating constraints* (performing agency in the real world). We define *foundations of agency* as skills and tools that help students see where change is needed and how change can happen. These are instances where students

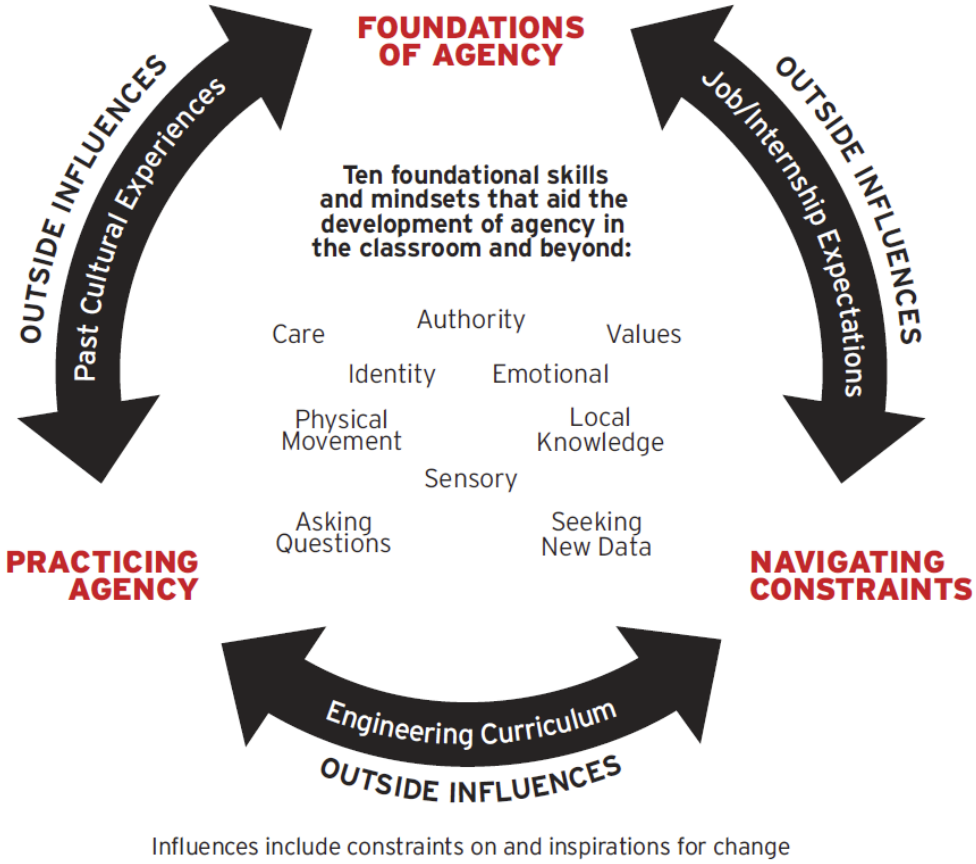

Figure 2 - A non-linear model of the development of student agency through STS Postures curriculum.

note how class activities help them understand how agency works in socio-technical systems (e.g., recognizing how various stakeholders make decisions, recognizing who and what are the levers of change, etc.). It also entails students identifying societal issues (especially ones in which they identify as being impacted by) and recognizing their significance, or taking a new outlook/perspective through class interactions. *Foundations of agency* are introduced through all four themes that students described as salient features of the STS Program [6]: developing an ethic of care for self and others, making the invisible visible in order to rectify hidden wrongs, and adopting a socio-technical systems thinking perspective to identify human and non-human stakeholders when attempting to understand an issue.

Practicing agency occurs in two basic settings in the STS program: classroom activities and community-based service learning courses. In the classroom, *practicing agency* refers to student expressions of agency that occur in the classroom that counter the banking model of education [16]. This entails students identifying and sharing their local knowledge and experiences as legitimate contributions to knowledge production in the classroom and beyond. In these cases, students feel empowered to express their own opinions and bring their own knowledge into classroom discussions and projects. We ask students to question the traditional classroom format and infrastructure, including how STS instructors administer classes. Practicing in the community are instances of student agency related to community-based course activities and

outside of courses, such as desires to change something about communities, the campus, engineering classes, and their lives in general. Agency to change communities involves skills and aspirations to disrupt the status quo and ask critical questions of science and technology.

Navigating constraints refers to performing agency in the real world and is the most theoretical dimension of the model. This study only follows students in the two-year STS program, so we don't have extensive data about how students use STS Postures to navigate constraints on agency in their internships and careers. We do have some data that speaks to how students navigate constraints in their engineering classes and identify possible constraints in future internships and jobs. We include this dimension in the model because it is essential for ultimately understanding how the STS curriculum encourages alternative expressions of agency. In our discussion below, we expand on future research that we hope to pursue along these lines.

These three dimensions (*foundational agency, practicing agency, navigating constraints*) of cultivating alternative expressions of agency require students to explore specific skills and mindsets (inside the circle). As part of building the model, we identified skills and mindsets we use in our courses to encourage alternative expressions of agency. Also, as we analyzed the data, we began to identify additional skills and mindsets related to practicing and expressing agency. For example, emotional agency is the freedom to express emotions and accept how they influence one's motivations and knowledge production outcomes (see Table 1 for other definitions). It may also show up as the agency to challenge and question authority, which could simply be the instructor, but could also be as expansive as the status quo of engineering culture (e.g., questioning the role of the military industrial complex in engineering schools). These various skills and mindsets of agency have relationships to pedagogical elements of STS Postures, but how and when they are activated is context and student experience-dependent. Table 1 connects the different agential skills and mindsets to specific STS Postures.

Table 1 – Definitions of specific skills and mindsets that catalyze student agency and their relationship to the STS Postures Curriculum. These are the skills and mindsets that populate the interior of the circle in Figure 2. The connections referred to here between STS Postures and skills/mindsets of agency are not limited to what is presented here.

Skills/Mindsets	Definition	Relationship to STS Postures
Emotional Agency	Connecting personal emotions and the emotions of others to our motivations and to diverse modes of knowledge production.	Emotion, Interoception, Making Meaning
Identity	Recognizing that identities are multiple and fluid and if empowered can lead to alternative knowledge from the standard positivist perspective found in engineering.	Making Meaning, Metacognition, Performance, Locating Power, Seeking Stories
Authority	Feeling empowered to challenge the authority of those in power. It also involves practicing what it means to have authority.	Locating Power, Performance, (Dis)Orientation

Values	Developing a self-awareness of how personal values can influence knowledge production for better and/or worse.	Emotions, Making Mean, Ethics in Artifacts
Physical Movement	Developing body and spatial awareness to cultivate situational awareness .	Proprioception, Play/Critical Play
Local Knowledge	Legitimizing student local knowledge in the classroom and other contexts.	Making Mean, Locating Power, Performance, Emotions
Seeking New Data	When questions arise, using a variety of data collection techniques to address the question.	Data Collection Techniques
Sensations	Using all your senses (smell, feel, hearing, sight, emotions, taste) to open up more channels for understanding the world around you.	Making Meaning, Sensations, Listening Contextually
Asking Questions	Overcoming dominant narratives of progress in order to develop habits of asking critical STS questions of science and technology.	Asking STS Questions
Care	Having a disposition for care and empathy, both for others and yourself. This should be the motivation for all science and technology.	Listening Contextually, Emotions, Ethics in Artifacts, Locating Power

Methods/Data Analysis

This analysis is based on data collected for a larger project studying the cultural practices of an STS program at the University of Maryland College Park between fall 2020 to spring 2022. Half of the study period students were online due to COVID-19 pandemic protocols and half the study occurred in the first year back to in-person instruction. For further details on that project see Radoff and colleagues [6]. Data used in this study were drawn from student interviews and classroom ethnographic observations.We should note that the original study that our current analysis is based on was not designed to specifically explore student agency. Rather, the original study design sought to explore general cultural practices of the STS program. It was from this analysis that the theme of student agency emerged. We subsequently decided to reanalyze the interview data and classroom observation data for more insights about student agency in the STS program.

The research team conducted interviews that explored the experiences of 36 first-year STS students in the program between January and March 2021. A limitation of this analysis is that the interview protocol was designed to elicit student responses about the cultural practices of the STS program, not specifically student agency. However, earlier analyses of this data [6] revealed alternative expressions of student agency as one of four salient cultural practices for STS students (see above). Since the first two authors of this paper felt this cultural practice is central to the program, they decided the data set should be reanalyzed from the student agency frame in hopes it would provide further insights and questions about student agency in engineering education. A sample of interview questions when student descriptions of agency emerged follows:

1) How do you think your participation in the STS program has made your college experience different than it might otherwise have been?
2) Tell us a story about how a typical STS class kind of goes.
3) How are conversations unfolding in these STS spaces? How are they similar or different from other spaces you've been in?
4) Is there anything that you think that STS courses do to specifically help create opportunities for social relations?

The research team also trained a team of undergraduate research fellows (URFs), who were members of the STS program at the time, how to make participant observations of STS courses [27]. Typically, three URFs made observations within a single course. Two of the URFs were external observers not enrolled in the course and one was enrolled in the course. The two external observers alternated class days and took detailed notes about student interactions with classroom activities, the instructor, and course guests. The embedded observer wrote detailed reflections about their experiences in the course. The research team sought permission to observe classes from the course instructor. However, while the instructor was made aware of the presence of the embedded student observer, their identity was not revealed to protect them. The research team held weekly meetings with external and internal URF observers to debrief their observations.

To more specifically frame our current analysis, the authors developed the model above, which scaffolded our observations through the three dimensions (*foundations of agency, practicing agency*, and *navigating constraints* in the real world) previously outlined.The first and second authors of this paper based these themes on how they scaffold the development of student agency in the classroom. The third author, a former STS student, helped frame these themes from a former student perspective. These sub-themes were then used in a thematic coding analysis of the interview data and course observation data for student expressions about developing agency in the STS program [28]. This analysis helped refine the model described above (e.g., identifying additional skills and mindsets students were using) and illustrate below how students are thinking about and expressing agency in and outside the classroom. The results presented below are preliminary, as we are still in the process of analyzing interviews and course ethnographic observations. Nevertheless, they provide insights about how the STS Postures curriculum is helping students explore and express alternative forms of agency.

Results

We organize our results based on our conceptualization of how student agency is being cultivated in the STS Program (Figure 2). We provide an example of how students are experiencing/taking up agency in each of the three major pedagogical standpoints associated with the student learning: *foundations of agency, practicing agency*, and *navigating constraints*. We focus on the ways each standpoint helps students build and practice specific skills and mindsets (Table 1).

Foundations of Agency

Data around the theme of foundational skills for student agency showed up in a number of contexts in the STS program. Particularly salient examples emerge from the assignment, "Community Futures," which was given to students taking the first year STS course in fall 2020. The first two authors of this paper designed this activity to get students away from screens and into their local environments as safely as possible. Students chose among several places to do an ethnographic observation, one of which was to visit a local park or "natural area" which they analyzed through the lens of Elinor Ostrom's [29] core design principles for good community practices. Their analysis had to consider these questions:

- What artifacts and/or ideas give the community a shared understanding of the space? Explain. (Ethics in Artifacts)
- What artifacts, ideas, and/or rules in the space facilitate community? (Ethics in Artifacts)
- What artifacts, ideas, and/or rules in the space is a barrier to community? (Ethics in Artifacts)
- Who has jurisdiction? Who makes decisions about the space? Who is potentially marginalized by these decisions? (Locating Power in Systems)
- What control do you have over decision-making in this space? How does it make you feel? (Locating Power in Systems)
- How is the space monitored? What makes people follow rules? Is the monitoring system fair? (Locating Power in Systems)
- How are conflicts resolved? What artifacts and rules are in place to do this? (Locating Power in Systems)

In the following sequence from a student interview, we see how the student used the above scaffolding to make a deeper meaning of a quarry near their childhood home:

> Interviewer: And so once you pick this place like a quarry, you said you had to ask questions like who had power? [W]hat else did you have to do to kind of analyze this setting?
>
> Student: Well, specifically-me specifically, I had to kind of like Google online, the like … what regulatory bodies oversee this? How do citizens submit complaints for them and when does this operate and who does this deliver stone to?
>
> Interviewer: Yeah, that makes sense. And what do you think was the sort of purpose behind this activity where you were analyzing a setting like a quarry?

> Student: Well, I think it was just a way to [observe] we're always going to live somewhere and there's always going to be something going on nearby.

The student above is showing a sense of agency by taking notice of the power dynamics inherent in managing a quarry. This quotation illustrates that the student is aware that the STS Posture of locating power is being practiced in this assignment. They are beginning to see the quarry as a socio-technical system where many stakeholder interests intersect, including the student's. Because the student chooses the location to analyze in the assignment, they are building a mindset that student local knowledge and interests are an important contribution to understanding socio-technical systems. This assignment also seems to awaken emotional ties to the quarry, which ties together the student's local knowledge and experiences with emotions. The student recognizes they are building an applied skill, "we're always going to live somewhere" and anticipates their future emotional connections to place. The combination of epistemological attachment and emotion also feeds into the identity of the student, as they connect what they are learning in class to their neighborhood. The mindset of *authority* is evident when the student explores "how do citizens submit complaints" as well as recognizing the power of the state and agency of citizens to steer state resources. An ethic of care is evident as well. The student is learning about the socio-political aspects of a place they care about and what they might have to do to bring change, if necessary. In short, they are pondering the levers of change that could apply to this location.

Practicing Agency

Practicing agency manifests in two basic settings in the STS program. We use the classroom to expose students to foundational skills and practice alternative expressions of agency that help students navigate their education and everyday lives. We also offer community-based service learning courses that provide opportunities to practice agency in real-world environments (e.g., robotics service learning in K-12 schools, assessing the safety and viability of infrastructure, etc.).

Agency in the Classroom: We encourage agency in the classroom through student-driven discussions, data collection, and activities that include movement (e.g., stokes, making observations outside the classroom, etc.). In particular, movement in the classroom is important. To counter the traditional teaching method of the professor at the front of the room and students in the audience, we make it a regular practice to disrupt this order. We sometimes ask students to arrange the room how they would like, create unfacilitated student breakouts, partake in activities that require mingling among classmates they don't know, and invite them to sit on the floor. The aim of putting students in a variety of postures is to help them see the various ways one can learn outside the traditional learning format (e.g., the banking model). We encourage students to incorporate their epistemological standpoints or partial perspectives through sharing their own experiences, opinions, and local knowledge in discussions and activities. Most student references to agency in the classroom point to interactions with other students, stakeholders, or instructors. The quotes in this section show how students are beginning to recognize their own agency in the classroom.

One student noted how STS classes try to de-center the instructor: “Well, you know, it's, uh, students are the ones who are driving these conversations when it splits up into groups and whatnot. Yeah. It's people talking with each other rather than being lectured at and taking notes for the most part.” In particular, this quote illustrates the value of student local knowledge and values as a cornerstone of the class. And while the notion of challenging authority isn’t explicitly mentioned, it is implied by the student’s recognition that certain aspects of the class are student-driven. Another student shares that when given the freedom to speak outside the presence of the instructor that it is “easier to talk about it and express our opinions and like what we thought about how it reflects in design and in society.” Here the instructor lets go of control of the classroom to give students space to speak freely about tough subjects like the relationship among race, science, and technology. This move allows trust to build between student and instructor, which creates a pathway for a more collegial or collaborative relationship with students rather than an asymmetric or adversarial relationship.

These conversations away from the instructor also allow students to feel more comfortable to relate subjects on a more personal level, especially for difficult conversations like the relationship between racism and technology: “We get to talk about questions. We get to talk about things that either relate to like us personally or just in general. I remember we had to talk about racism at some point in the first semester and like how it relates to design and stuff. So even though we're talking about social issues, we're still looking at it in kind of a design perspective.” Another agency mindset that the student speaks about is a self-discovery process for identifying seemingly unconnected relationships. Initially many of these students express frustration that we talk about seemingly unrelated topics like the connection between racism and technological design. However, through self-exploration they are encouraged to practice making connections, even if it is hard and initially off-base. In this sense, they are taking risks and discovering ways to seek new data. They talk about “questions” and how to answer them by making tentative connections that require further research.

The last connection to student agency in the classroom we want to share is how identity and personal experiences shape one’s interpretation of technology. One student shared their insight about an assignment where multiple students were asked to interact and share meaning making around the same technological artifact, in this case, a vacuum cleaner: “And after we did that activity, we would, uh, collaborate with group members and share our different experiences in the discussion sections. And I think that was pretty, uh, interesting and fascinating how different people could have done a similar task, but they had a different takeaway from me.” In this activity, the student realizes that different people make different meanings out of the same technology. They implicitly begin to understand that people’s identities shape how they perceive technology and that would result in “a different takeaway from me.” This insight is a step toward the freedom to express different identities is acceptable and perhaps even desirable, as it leads to diverse insights and local knowledge.

Agency in the Community**:** The example here occurs in the context of the second author’s Infrastructure and Society course in spring 2021. Infrastructure and Society is an experiential-based practicum course where students learn about infrastructure issues in a local community. The student goes on to reference the disability audit assignment in which students are learning observation data collection techniques for identifying accessibility issues within a community:

> "They [the STS instructors] [r]eally emphasize … STS thinking skills [STS Postures] at first. And I was kind of just like why? Um, but I mean, when you read about them, you kind of get like what they're trying to do. [T]hey're sharing like these like core ideas that like, I guess good engineers or people within stem should have. And so like one of the ones that I think about a lot is [listening contextually]. And I think just being able to listen to others and their needs and like different perspectives [can]... [c]ontribute to like meaningful change and improvements. And then like an example of this was in the infrastructure class [where] we were looking for infrastructural issues, um, within our community. And, uh, someone had shared a picture of their local target and how there was a handicap, like parking space that was like right next to the stairs, but it was like right next to the entrance, but to the stairs. And so. I guess the designers are like, oh, well it's right next to the entrance. But like the ramp was on the other side of the parking lot. So it's like, you kind of see what they were trying to do, but they just totally missed the mark. And all I could think about was when I was looking at this picture, I was like, well, if they just had like more diversity in their group and just more perspectives, this issue could have been easily rectified, but this was just so careless. And so I think like when they share these STS thinking skills with us, one of them being listening contextually. It will then help motivate us to seek out different perspectives to them, like actually be effective in what we do."

In this passage, the student expresses frustration with how an accessibility ramp is poorly designed. This response is an example of how emotional agency links to the critique of authority (ramp designers) and challenges the designers' epistemological assumptions about ramp design. The student is simultaneously practicing several mindsets and skills that are key to catalyzing community change. First, by naming a practice "careless" the student expresses involvement in what is at stake. Locating power, they challenge the authority of the designers and question a knowledge production practice that doesn't include "a diversity of voices." The student also tries their own hand at authority by recognizing a design critique that is epistemologically appropriate for them to have. The student's solution involves the STS Posture of listening contextually, which would allow for the inclusion of local needs and concerns of a variety of stakeholders. Taking the perspective of people with disabilities to critique this design is a practice of care (to include diverse perspectives). And as with previous examples, this ethic of care motivates the student's desire to include multiple voices and rectify the perceived wrong.

Navigating Constraints

Since we only have indirect data on how students perceive *navigating constraints* in the real-world, we first offer a description of STS program activities that help students think about constraints. We follow this description with data that shows how students imagine *navigating constraints* beyond the STS program.

When working with students on navigating constraints, we consider three things: locations, modes of navigation, and classroom strategies. In terms of locations, this could include workplaces, (in future careers and internships), engineering classes/college life, and also communities, families, their K-12 experiences, and any situation in which a person finds themselves taking on the identity of an expert (this could be a family situation). What modes are there for navigating these constraints? STS Postures are possible modes for *navigating constraints*: taking responsibility for collecting data on potential harms, identifying leverage

points for change (e.g., advocating for policies or, more generally, establishing relationships with political functionaries to cultivate empathy), asking questions, approaching people in positions of higher and lower authority, and going beyond standard ethics codes (we may touch on these in class but they are not the backbone of our courses).

What specific classroom strategies have we put in place to simulate how it feels to navigate them? We run simulations, discussions and participant observations in which students practice ways of effecting change by challenging the "culture of disengagement" within engineering schools [1,4]. Many, if not all, STS courses start the semester with a quick exercise to "locate ethics in artifacts" in the classroom as a modality for challenging mindsets of authority and setting the stage for student-student and students-professor collaboration (co-construction of knowledge). In the infrastructure courses, students use data from multiple data collection techniques to identify "*something I could report*." Then they brainstorm ways they might report it and finally, they must take one step, such as emailing or calling someone. In the science communication course, students in pairs must find and interview a graduate student willing to explain their research in just a few minutes. To challenge technical narrowness and the socio-technical divide, students research who represents them using an app such as Balletopedia or Common Cause. To explore the mindset of the military industrial complex, students read case studies and examine the most recent data of political contributions from this sector. In the Robotics Service Learning Course, students use the model of multiple forms of capital to code a fellow classmates' personal history, which helps challenge the primacy of neo-liberalism and capitalism as forms of power and agency. Metaphor analysis, described in the STS Postures as a data collection method, helps challenge the myth of objectivity by highlighting the cultural situatedness of scientific information (e.g., biological systems being described as Five Kingdoms).

How are students relating these activities to *navigating constraints* outside the STS program? Our data shows that some students are imagining how STS curriculum influences the ways they think about their engineering courses and how it might come into play in their internships and careers. In terms of navigating the norm of technical narrowness and technical-social dualism in engineering courses, one student explained, "I think the biggest thing is [STS has] given me a different aspect to what I do in my engineering classes and what I'm learning with the design and even just things like Mechanics I. You kind of realize that like, yes, this is something that's technical and something that I'm going to be doing often, but also like there are social factors that influence why I'm doing what I'm doing." In another account, URF Fellows observed a student in the Infrastructure and Society course challenge the authority of a practicing engineer. This course partners with professional engineers who train STS students to assess the safety and viability of buildings. One of the engineers was directing a class activity that reviews the assessment model used in the course, when a female STS student openly called into question the veracity of a fact given by the engineer. At first the engineer resisted the challenge, but through support from her classmates and the course instructor, the engineer eventually admitted the student was correct.

Beyond the classroom, students mentioned the struggle with gender politics that might happen in the workplace: "I think equality in the workplace between men and women especially, but also just all genders and all sexual orientations. I think that's very important and that's something I think about very often just because, you know, like you said, women are so very

underrepresented. So going into the workplace, we're also still underrepresented. And that can be reflected in a lot of different ways." This student is coming to grips with the norms of engineering that privilege the male over other genders [30]. Another student wrestled with the role of corporations and entrepreneurial behavior on the development of technology:

> "I think STS did help me... look at it from a different perspective. Where, for example, on the Mars Landing, they are planning to,... Elon Musk, I'm pretty sure is planning to establish life there after the travel has been successful and there has been settlements made. And I think a combination of the values that I learned from STS and STS thinking helped me realize and question what would happen, like if America was to be the first country to get to Mars and establish successful civilization there, would the rules that the civilizations go by be the same as the ones in America? Would the civilizations make their own constitution? And would there be, would that be the constitution for all settlement on Mars?"

Here the student wonders what values will govern the people and technology that end up on Mars. They see that how this will play out could manifest in a variety of ways and that pre-existing cultural norms will probably exert a strong force on what happens. In our last example, a student imagines how the STS Posture of locating power is critical to getting things done in the real world: "Especially the locating power in systems, really just to identify means of change and like it really can stretch beyond STS. And just understanding, if you want something done, maybe I should go talk to this person. If I rally enough with the people who are affected by it, maybe we can get some change done. And so, it's just an idea that I feel like can be used beyond STS." This student is breaking the norm of the engineering ideology of depoliticization. They acknowledge that to "get some change done" they need to engage with others and perhaps even move in a collectivist fashion.

Discussion

Our preliminary analysis starts to sketch ways student agency can be catalyzed. The "skills-and-mindset approach" associated with STS Postures contrasts with content-driven, instructor-centered pedagogy of most engineering classes. We see several promising trends. First, we have identified at least 10 foundational skills and mindsets that aid the development of agency in the classroom and beyond (see Table 1): emotional agency, expression of identities, challenging authority, awareness of values, physical movement, legitimizing student local knowledge, seeking new data, developing an ethic of care, activating all our senses, and asking critical STS questions. Cultivating these mindsets and skills require iterative practice with carefully structured assignments. They help students improve self-awareness about the connections between their body and mind, be empathetic of others, and see levers of change; practice interacting with peers and instructors as collaborators in the classroom; and practice outside the controlled environment of the classroom (community engagement). The experiential learning focus of the STS Postures curriculum provides scaffolding for this to happen. Regardless of the curriculum one uses, we hypothesize (as our results are preliminary and tentative) that cultivating alternative expressions of student agency to challenge the status quo of engineering education should seek the following outcomes:

- Develop tools that help students recognize the levers of change (i.e., power) and how they might go about convincing people that change is needed (e.g., who are the change agents they must engage with).
- Creating the space to express and experiment with identities. This helps students become comfortable with others and see how identity isn't fixed, which ties into the perspective from which they produce knowledge and solve problems [24]. The free expression of identity has two positive benefits. First, students are free to tie their identity to how they want to be an engineer [13]. Second, understanding identity is a pathway for students to trace how difference drives the way people perceive and use technology, and ultimately, that there are multiple pathways for developing technology.
- Students should be empowered to express their agency in the classroom (e.g., autonomy to speak up and bring in their own ideas and concerns, the ability to challenge the status quo of the classroom, feeling they have freedom to make choices in their own education, or acting to make a significant change in how education works on campus) [3]. If students don't have permission to challenge dominant modes of knowledge production in the classroom, they are unlikely to do this in their professional careers.
- Students should be encouraged to be active agents and collaborators with those in their communities, personal and professional. Developing an ethic of care and empathy for others is one step toward designing and building culturally appropriate and just technology [5].

None of these skills and mindsets will be useful outside the context of the university setting unless we help students navigate the constraints against personal agency they will encounter in their jobs and daily lives [20-21].

Future Research

As noted above, this paper grew from a study to identify salient cultural practices within the STS Program. Future research could inquire more specifically about the catalyzation of student agency. As previously noted, a limitation of our analysis stems from the fact that data used in this analysis comes from interview and observation protocols not specifically designed to understand student agency. Nonetheless, two pertinent avenues of future research on personal agency in engineering education and engineering careers emerged from this analysis.

First, it is important to develop an interview and observation protocol that focuses on understanding various ways of cultivating alternative expressions of agency through the STS Postures (or other curriculum designed with the same goal in mind). Through our model, we identified three salient areas to explore further: 1) cultivating *foundations of agency*; 2) *practicing agency* in the classroom and communities; and 3) *navigating constraints* beyond the program. Each could be the focus of a study. For example, the skills and mindsets we identified related to cultivating agency could be examined more closely (Table 1). We identified ways that they are related to STS Postures, however, we don't have a good understanding of how and when they are activated. How do foundational skills translate into practice? What foundational skills are most relevant to cultivating alternative expressions of student agency? What classroom exercises or other experiences lead to expressions of these skills? How much practice do students need to take ownership of these skills and mindsets? How do these skills and mindsets manifest

beyond the 2-year program? In short, we do not know whether students are developing skills/mindsets equally in the different facets of agency cultivation in our model.

Second, we could only speculate on ways that the STS Postures curriculum might impact student thinking on agency beyond the 2-year STS program. One promising approach would be to interview alumni from the STS program, or similar programs, about their upper level engineering courses, internships, jobs, or graduate studies. This type of study would help us understand how mindsets and skills cultivated in the program weather cultural and social constraints engineers encounter later in life. We believe this type of study is critical to developing effective pedagogy related to student agency. If we don't understand whether and how insights and norms from STS Postures (or other curriculum with similar goals) is sustained in later endeavors, we are maintaining a blind spot in liberal engineering education. Many of us are attempting to change engineering culture, however, we need a long view of what is happening with our pedagogical frameworks so we can iteratively adjust them to improve long-term outcomes.

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