

Examining the “narrow” and “expansive” socio-technical imaginaries influencing college students’ collaborative reasoning about a design scenario

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The central thread of my education over the past decade has been physics and astronomy; I earned undergraduate degrees in both at the University of Maryland, followed by a Masters and PhD in astrophysics at UC Berkeley. In that time, I published original research in a range of sub-disciplines, including instrumentation of adaptive optics systems for ground-based telescopes, and the detection of isolated, stellar mass black holes. For my doctoral thesis, I conducted a study on the experiences non-white, non-male PhD candidates in astronomy across the US to understand the relationship between the culture of academic astronomy and the persistence of identity-based inequity in graduate programs. This work (which was inspired by my own experiences as a graduate student in astronomy) built upon my background in physics education research from my undergraduate days, when I began working as a Learning Assistant (LA) with Dr. Chandra Turpen. My experience as an LA introduced me to PER, and gave me the opportunity to get involved in curriculum design and research as an undergraduate. After my PhD, I returned to Dr. Turpen’s group as a postdoctoral researcher, and have since redirected my focus to the study of ethics and institutional change in STEM higher education.

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Introduction

As more social problems are relegated to the domain of engineering, it is becoming increasingly important to train ‘holistic engineers’ [1] who are equipped with systems-thinking skills and who consider the macro-ethical implications of their decisions. However, the trends appear to be moving in the opposite direction. Cech [2] reports on a growing ‘culture of disengagement’ amongst engineering students, whose concerns for public welfare appear to decline over the course of their education. Similarly, Schiff et al. [3] found that while some engineering students arrive in college with a strong sense of personal responsibility, it is often disconnected from their sense of professional responsibility, where they tend to center micro-ethical rather than macro-ethical concerns.

Many scholars attribute this decline in professional responsibility for human welfare concerns to cultural ideologies prevalent in engineering education and in broader society, such as depoliticization of engineering practice, technocracy, and meritocracy [2] [4]. These ideologies limit what is possible in design work by constraining our socio-technical imaginaries, which, according to Lambrinidou and Canney [5], “define in the most elusive of ways the self within the whole, the self’s relationship to others, and the norms of accepted and expected social behavior in the context of a larger moral order...they infuse themselves into everyday forms of expression (e.g., stories, images, day-to-day routines) in ways we rarely notice. And once adopted, they are viewed as natural, the only vision of social life possible” [5, pp. 2]. These socio-technical imaginaries can be both tacit and highly consequential for how people engage with the world. And because of the dominance of certain values in society, some socio-technical imaginaries are more accessible than others.

For instance, Riley [6] (drawing on Pawley [7]) notes that the omnipresence of private, for-profit organizations in engineering promotes managerialism, which views “human relationships within the organization through a lens of inputs and outputs and increasing organizational efficiencies by minimizing inputs and maximizing outputs” [6, pp. 40]. These narrow imaginaries prop up the status quo and naturalize dehumanizing relationships and practices like commodifying people based on their work production. Furthermore, technocratic ideologies shape our assumptions that technological advancement is unproblematically good, that widespread access to technology will benefit everyone, and that technical experts are the only people qualified to make contributions and decisions about technological development and implementation. Technologies and the way they are implemented, however, are not value- or power-neutral; they are entangled with capitalism, racism, classism, ableism, etc., and wield great influence over our social structures and relations [8]. At the same time, they create distance between the engineers who develop or implement them and the people they impact.

In an attempt to challenge the cultural ideologies that narrow engineers’ socio-technical imaginaries, programs like the Science, Technology and Society (STS) program at the University

of Maryland in College Park, engage students in human-centered design and systems-thinking to provide on-ramps for more expansive thinking that aims to disrupt the status quo and to grapple with the ethical implications of engineers' work through a critical examination of "How," "For What," "For Whom," and "With Whom" students engage in design work [9]. In this paper, we present a preliminary analysis of first-year STS students collaboratively reasoning through a simulated design scenario about a small community store facing challenges related to the COVID-19 pandemic (adapted from [10]). Using discourse and narrative analysis, we analyzed multiple focus group conversations to identify common "co-occurrences," or ideas that hang together in participants' reasoning, to identify the variety of ways socio-technical imaginaries play out in students' design thinking.

Theoretical orientation

In this paper, we use the theoretical construct of socio-technical imaginaries [11] to understand how students' design thinking might be limited by common narratives and problematic assumptions about socio-technical systems ("narrow thinking"), as well as what might enable them to break free from these limitations ("expansive thinking"). We define "narrow thinking" as adopting the status quo cultural narratives of engineering that privilege uncritical endorsement of instrumental technical solutions, depoliticizes engineering practice, is deeply entwined with corporate interests, and reduces the public to passive recipients of technology or positions them as part of the problem that technologies are adopted to solve. In contrast, we characterize "expansive thinking" as breaking free from these status quo narratives and attending to science and technology from a human-centered, systems-level perspective. This mindset promotes socio-technical solutions which take into account the social, cultural, political, and environmental context of a problem, extends beyond instrumental goals of increasing productivity and efficiency, builds empathetic relationships with the public, and centers the values of justice and human welfare.

We follow Jasanoff's [11] definition of socio-technical imaginaries as "collectively held and performed visions of desirable futures...animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" [11, pp. 19]. When STEM undergraduate students arrive on campus, they have been participating in the larger, national-level socio-technical imaginaries that percolate through their K-12 STEM experiences. We can generally see these imaginaries reinforcing a prideful, but narrow U.S. narrative of an innovation-driven economic system driven by the need for constant technological advance. And the fervor for this kind of socio-technical imaginary is further buttressed by recruitment material, campus messaging (e.g., "fearless ideas"), and STEM faculty (see [12] for this broader trend in higher education) through what Hilgartner [13] calls "vanguard visions": futuristic projections of revolutionary public benefits resulting from emerging technologies. Often these imaginaries are constructed without any direct consultation with the public, which often creates a mismatch between science and technology development and the priorities of the public. While such imaginaries are generative for those that benefit from the status quo of innovation (e.g., large corporations, the military, upper middle class), they also largely exclude—while saying innovation will benefit all—many segments of society such as people of Color, women, rural populations, and low-income families [14].

Socio-technical imaginaries open up possible futures for some and close down futures for others. In this sense, they can create a path dependency that limits imagination. And since many STEM majors come from privileged backgrounds and benefit from promissory innovation imaginaries, these socio-technical imaginaries become the resource pool most STEM students draw from for their own imaginations. This was evident in a study exploring the challenges of integrating socio-technical systems thinking into technical engineering courses [15]. The study found that socio-technical systems thinking activities did help students bridge the social-technical divide. However, the study revealed that just over half of the connections made between the social and the technical were explained through common, “narrow” social constructs like free market idealism (e.g., productivity, convenience, and efficiency) or blaming human behavior for the failures of technology (e.g., adopting the technological neutrality thesis) [16]-[19]. In short, when asked to make social connections, the students were drawing from the limited imaginaries they had participated in their whole lives.

Socio-technical imaginaries can be entangled with problematic social structures that amplify inequalities and other negative consequences that inevitably emanate from the pursuit of science and technology. These problematic social structures create a form of path dependent thinking that exclude the invocation of imaginaries aligned with the socially just application of technology. Science and technology studies provide several theoretical frameworks that we build on to help us identify and understand the ways these social structures can narrow and constrain engineering practice. We draw on four frameworks that help us understand the different types of relationships STEM students typically have with technology: the types of solutions engineers rely on (i.e., technological fixes), who engineers think count as valid stakeholders and how they conceptualize and develop relationships with them (i.e., deficit/threat models), the market-based systems and contexts that shape the imaginations of engineers (i.e., neoliberalism of science and technology), and the dominant social values and power relationships engineers are operating with (i.e., technological frames).

The STS framework “technological fixes” helps us theorize what happens when societal challenges are reduced to technological solutions, which tend to only treat the symptoms of an issue rather than the root cause (e.g., surveillance cameras to stop crime) [20], [21]. The tendency to address societal challenges through technological solutions—a commonly adopted identity of engineers—limits the problem solver’s imagination [5]. Many corporate and governmental entities adopt knowledge deficit models of the public [22] and/or public threat models [23], [24], [5] that erect detrimental boundaries between the public and engineering efforts. These models, which characterize people as unknowledgeable or a threat to agendas, marginalize oppositional and alternative voices. The neoliberalization of scientific practice and higher education reduces innovation and maintenance of current systems to the logic of capitalism, marginalizing community-based and government-driven science for the public good [12], [16]. Lastly, the concept of technological frame describes the social process by which socio-technical systems become status quo and impervious to change. It focuses on the formation of power relations among stakeholders that have a vested interest in the success of the systems [25]. Each of these frameworks help explain the presence of common social structures that could narrow the imagination of an undergraduate engineering major and are generally intertwined with the socio-technical imaginaries of engineering education institutions [6], [26], [27].

While engineering education and STS scholars have made significant strides in advancing our understanding of the root causes of narrow thinking among engineering students, they have only just begun exploring ways to disrupt narrow thinking and cultivate more expansive ways of approaching the design and implementation of technology. Some scholars have begun to question what a shift to more expansive socio-technical imaginaries that center human welfare might look like, and what ideologies, values, and structures might support them. A more general recommendation for overcoming an overreliance on technological fixes, building better relationships with the public, transcending market-based solutions, and changing the innovation for the sake of innovation framing of technological advance has been to adopt a social justice framing of a socio-technical systems approach to engineering education (e.g., [27]). Many of these approaches argue at a theoretical level for a re-envisioning of national and programmatic agendas to center human rights and capabilities (e.g., Nussbaum [28], who orients to values like bodily health and integrity, the ability to experience emotions and to form relationships and attachments to others, and the right to wield control over one's material environment) and take asset-based approaches to community cultural wealth (e.g., Yosso [29], who highlights six dimensions of cultural capital—aspirational, linguistic, familial, social, navigational, and resistant capital).

Drawing on some of these traditions, Riley and Lambrinidou [30] conducted a thought experiment to imagine what the field of engineering might look like if instead of promoting values connected to the military-industrial-academic complex, it adopted professional codes founded on social justice. They looked at ethics codes of social workers as inspiration for what it looks like to center the needs and autonomy of clients, to engage in practices of informed consent, and to value clients' cultural competence and social diversity. Using these ethics codes as a model, they developed ethical principles for engineers based on values of service, social justice, cultural and epistemic humility, dignity and worth of the person, importance of human relationships, and peace. In doing so, they discourage the essentialization of what it means to practice social justice in engineering to any one set of principles and instead encourage engineers to listen carefully to the communities they aim to serve, to first develop a deep understanding of how marginalization plays out in those communities and what social justice means to them.

These various orientations stand in stark contrast to current agendas centering neoliberal and capitalist values and suggest alternative socio-technical imaginaries that have the potential for more liberatory systems and social orders. It is only in the last few decades that concrete applications of this more human-centered approach have begun to multiply under such names as creative anticipatory ethical reasoning [31], making and doing [32], imploding artifacts [33], systems thinking competencies [34], among others. While this is promising, we have very little understanding of how these approaches disrupt narrow thinking and develop habits of expansive thinking. This study attempts to expand our understanding of how a socio-technical systems approach at an STS program at the University of Maryland might do some of this work.

Study context

The Science, Technology and Society (STS) Program at The University of Maryland

The setting for this study is a “Science, Technology and Society” (STS) program sponsored by the College of Engineering at the University of Maryland College Park. Through the dedication of its directors, instructors, and other support partners, this program seeks to counteract the technical narrowness of preparation many students encounter within engineering and other STEM programs. The program focuses on cultivating macro-ethical and social justice orientations towards the study and design of socio-technical systems [35]-[37], [3]. STS students take two years of ‘colloquium’ and ‘practicum’ courses that are designed to provide students with foundations and field experiences focused on service learning and community engagement. The program cultivates students’ critical understanding of and engagement with socio-technical systems through the practice of various systems thinking skills, like “locating power in systems” and “looking for ethics in artifacts.” It encourages students to take a sociocultural approach to knowledge construction, with a focus on valuing multiple perspectives, questioning the status quo, and recognizing who might benefit or be harmed by socio-technical systems and innovations. A detailed account of how these systems thinking skills are cultivated in the STS program can be found in [15].

Our study seeks to understand the cultural practices that support ethical engineering

Our research collaboration took place within the context of a larger NSF-funded research study exploring whether and how extended immersion in cultural practices of the University of Maryland STS program supports students’ macro-ethical reasoning about the world and their personal and professional responsibility within it [36], [37], [3]. Our approach to this research study integrates “outsider” (researcher leads’) and “insider” (participating students’ and undergraduate research fellows’) observations of and reflections on culturally salient events, activities, and artifacts to create ethnographic accounts of which cultural practices [38], [39] are consequential for shaping engineering students’ macro-ethical reasoning and identity. In this study, we followed students longitudinally over two years of the STS program and developed accounts of how individuals do and do not take up STS cultural practices and bring elements of those practices into other settings. Data sources include ethnographic observations collected in STS courses, video-recorded interviews with participating students about their backgrounds and experiences in the program, and video-recorded focus group interviews in which students collaboratively reasoned about complex design scenarios. This paper focuses exclusively on our analysis of a subset of focus group interviews, conducted virtually during the Spring of 2021.

Development of the focus group prompt and our approach to facilitation

In designing the focus group prompt, we started with some initial heuristics. We wanted the design scenario to connect meaningfully to students’ lived experiences and knowledge bases, and to invite students to draw on the human-centered design tools they had been exposed to in their STS program. From past collaborations, we were aware of a grocery store design prompt that our colleague, Dr. Ayush Gupta, had adapted from engineering education researchers and educators

(credit for the design of the original prompt goes to David Radcliffe, Robin Adams, and Monica Cardella at Purdue University). The original (2011) formulation of this prompt was: “A grocery store is losing customers because they have become annoyed at how long it takes to check out. There is not space in the store to add more checkout lanes, but something must be done. You are hired as a consultant to help the company” [10].

Through Dr. Gupta’s use of this prompt in his own introduction to engineering design course (see [10]), Dr. Gupta iteratively developed a lesson around this prompt and began tinkering with it. They describe changing the text of the prompt to read: “What do you think would be the impact on society, economics, corporations, owners, workers, etc. if the solution was scaled up for use across many stores?” Dr. Gupta observed that the addition of this prompt in their class resulted in attention to new stakeholders: “widening the span of who is impacted” and “notic[ing] the links between different individuals/communities” ([10], pp. 7). Dr. Gupta describes these modifications as creating new opportunities for drawing students’ attention to two aspects that challenge technological determinism: “(1) The work of engineers is situated in communities of people and has consequences, for better and for worse, for people not unlike them; that improvement in quality of life is not the inevitable outcome of technological development, at least not for everyone. And (2) social and political power, in part, shape how engineering solutions are implemented and influence who accrues the benefits of new technological developments and who does not” (10, pp. 8). This instructional account in the literature gave us confidence that this design scenario could prompt interesting macroethical considerations and invite complex socio-technical reasoning.

Driven in part by a similar motivation to disrupt technological determinism and to draw greater attention to issues of social justice, project leads, Dr. Chandra Turpen (a co-author on this paper) and Dr. Logan Williams, made further adaptations to this grocery store prompt for the purposes of this study. Discussions between Dr. Turpen and Dr. Williams surfaced a shared commitment to seeing human-centered design work pay greater attention to how power is structured in society, to social inequities, and to issues of social justice. These commitments drove our decision to layer in: (a) the COVID-19 pandemic context (by cuing “social distancing” and “spreading”), (b) social inequalities into the prompt (by cuing “low-income community”), and (c) health considerations (by cuing “underlying health conditions”). We also wanted students to think about *how* they would go about solving this problem, rather than only focus on describing possible solutions. With these considerations, the design scenario prompt for our focus group participants was the following:

A small grocery store in a low-income neighborhood has "long lines" and has hired your group to make a plan to solve this problem. The store is following their state and county guidelines for social distancing due to COVID-19, which has just started spreading. Some employees had to quit because of employer policies and/or underlying health conditions. However, even with the state-enforced reduced capacity, the store check-out lines get very long. The remaining employees have even seen customers at the back of the line just putting down their items and leaving the store. Therefore, the store is losing money because of this problem. How might you go about solving it?

Groups of 2-4 students were asked to spend about 1 hour collaboratively discussing the scenario and generating and evaluating solutions, with support from a facilitator.

In facilitating focus group discussions, we drew from Dr. Gupta's accounts [10] of facilitating their lesson with engineering students and prepared some specific prompts in advance. We wanted to invite students to orient to this setting with some humility by prompting some information gathering, so we often asked, "What additional information would you want to know to inform your design process?" We also wanted to explicitly invite students to connect their design thinking to concepts and ideas that had been exposed to in their STS program (if they hadn't come up spontaneously), so we asked students to "consider whether the STS thinker skills might produce any insights in the design work" [15]. These focus groups were semi-structured spaces where facilitators engaged in substantial improvisation. Some principles for facilitation included: wanting the conversation to be in a "sweet spot" between divergence and convergence, noting problematic ideologies and supporting reflection on it without demonizing participants, promoting equitable participation (e.g., redirecting to students who haven't talked much), and supporting deeper reflection into systems of power and ethical dimensions of the problem.

Designing the composition of focus groups

Based on our initial one-on-one interviews with STS first year students between January 2021 and March 2021, many students reported that an initial group-based project in the first-year colloquium seminar of the STS program was quite impactful. They described creating meaningful bonds with their teammates in the process of diving into the group-based stakeholder interviewing assignment together. We drew on this understanding of the STS community to deliberately group students with others who they had familiarity and congeniality with, which we thought would facilitate their collaborative design work. We looked at the list of STS students that volunteered to participate in our research study and composed the focus groups such that as many groups as possible included students from the same colloquium project group, or at least the same recitation section from the Fall 2020 semester (which was a 2-credit course). This formulation worked out for most of the groups, with only a few exceptions.

Analytical approach

Preliminary analyses

With support, mentorship and feedback, our team of undergraduate research fellows (URFs) [40] developed extended written analytical memos focused on a single Focus Group (FG) transcript. Using an analytical approach modeled after [41], research fellows focused on diagramming the constructions of people and ideologies across different segments of the FG's conversation. The resulting claims, each grounded in a single FG transcript, set the foundation for future analyses across FG transcripts and served to hone our attention to multiple characteristics and dynamics of students' design thinking.

Following our collaborative work with the URFs, co-author Dr. Jen Radoff led analysis looking across FG transcripts. Her cross-transcript analysis identified a pattern—which some URFs also noted within specific interviews—in whether participants framed the context in relation to small

community stores or big-box stores. This made a difference for how they constructed stakeholders and the kinds of solutions they considered (e.g., more technocentric vs. socio-technical). When participants conceptualized the store as a small community store, this tended to cue up stores as places where you might go to forge meaningful connections with others in your community. Conversely, when participants conceptualized the store as a big-box store, this tended to cue up stores as having generic qualities, utilizing “cutting-edge” technologies, and needing to maximize profit and serve the many customers as efficiently as possible.

As our team continued our cross-transcript analysis, co-author Dr. Fatima Abdurrahman identified a pattern in the ways students engaged with the dimension of class in this design scenario. She identified at least three persistent ways that deficit narratives about “low-income community” were arising in focus group transcripts: (a) as limiting resources available for solutions, (b) as limiting exposure or access to technology, and (c) as characterizing low-income neighborhood residents as untrustworthy. These empirical themes connect to patterned ways engineers orient to the public [5] and prevalent myths in society about poverty [42]. These cross-transcript analyses left us wondering whether there might be connections between the ways participants conceptualized the store context and the ways they characterized various stakeholders, particularly low-income community members, as well as the role these different imaginaries played in episodes of students’ “narrow” or “expansive” reasoning.

Identifying “narrow” and “expansive” focal segments

Guided by our initial analyses, the co-authoring team (including a subset of the URFs—Amol Agrawal, Danjing Chen, and Sona Chudamani) returned to the full set of data with the question, “How is our imagination being constrained by current social structures in society and when does it break free from these narrow constructions of engineering practice?” From the set of twelve interviews, we selected two FG interviews for closer analysis, which had evidence of both “narrow” and “expansive” reasoning. These focus groups were: Malik, Serena, Molly, & Joanna (M+S+M+J) and Dustin & Harveen (D+H) (all pseudonyms). Within these FG interviews, our co-authoring team collaboratively identified candidate focal segments that: (a) exhibited highly “narrow” design thinking where implicit assumptions about the status quo were dominating the imagination, and (b) exhibited more “expansive” or liberatory design thinking where participants were exploring alternative socio-technical solutions that attend to people’s basic human rights and needs. The “narrow” segments from these interviews were representative of the narrowness evident across the full data set in that the solutions and reasoning were all very similar across the data set. However, the “expansive” segments resulted in more systems-level thinking and thus provided more diverse entry points for problem solving, so there was not a “typical” way these segments tended to play out across the full data set.

Our research team is interested in modeling both the themes in students’ reasoning that tended to arise together (what we called “co-occurrences”) and the key discursive moves that resulted in qualitative shifts in the nature of the design work (what we called “pivots”). Because we see the modeling of co-occurrences as laying the groundwork for future explorations of pivots, we focus this analysis on modeling co-occurrences. In our analytical approach, co-occurrences can be characterized as local stabilities of conceptual, ideological, and axiological reasoning, while also

expecting that “students’ reasoning (and cognition) about socio-technical issues are highly sensitive to context and dynamic rather than stable or belief-life” ([41], pp. 21).

Four analytical foci for modeling co-occurrences within design discourse

In our analytical approach, we began to externalize what aspects of the discourse we were intending to capture and which aspects of the discourse we intended to background. We settled on four central themes that tended to come up in coupled or networked ways, and that captured insights that emerged in previous analytical work. These four themes were:

1. **Solution type.** What types of solutions are being generated?
2. **Store context.** How is the store context being modeled?
3. **Construction of people.** What qualities of actors are elaborated and how are their needs being constructed in relation to one another?
4. **Values.** What values are being centered or prioritized in evaluating possible solutions or approaches?

Solution type. When considering the types and qualities of solutions that are generated, we took Dr. Gupta’s [10] observations as starting points. Dr. Gupta’s firsthand accounts of using an earlier version of this grocery store prompt in an introduction to engineering design course identified some of the common types or common patterns of solution generation and features of those solutions. Often there was a progression from *more technological solutions*, towards *human resources management approaches*, and then sometimes (though rarely) *solutions that oriented to human welfare*. We started with these as common “solution types” that also arose in our data. However, we also recognize that, at times, two solutions that are highly similar on the surface could play out in different ways. For example, adopting an app-based solution at times played out in more of a technocentric way (e.g., when foregrounding a user’s ability to scan items and check themselves out with their phone) and sometimes in more of a human resources management way (e.g., when attending to the ways that an app can support “timed entry” to minimize health risks to employees and customers in the store).

Store context. We also recognized that the design scenario introduced some characteristics of the store as a setting (e.g., “small grocery store,” and “in a low-income neighborhood”), and these characteristics were considered or ignored to varying degrees in particular segments of the design reasoning. For example, participants would at times reference big-box stores like Target, Walmart, or Costco, and ideas about being a small grocery store in a low-income neighborhood would be entirely ignored. At other points, students paid attention to how possible features of the store context might impact the design of solutions, such as if the store is in a rural or urban context, or what transportation systems shopper might be relying on.

Construction of people. Another focus of our analysis was the cultural construction of people or actors in the design discourse. This approach builds off of [41], in modeling the relational constructions of people in different segments of the conversation. This analytical focus is guided by asking questions about: (a) what is the cast of characters elaborated, (b) how are qualities of those characters playing out in the storytelling, (c) how are these characters being constructed in relation to one another, and (d) whose values/needs are being centered or marginalized. This

dimension of analysis oriented to the tacit assumptions underlying the construction and positioning of people in relation to one another, and the ways that participants' discourse operated to humanize or dehumanize various actors.

Values. The last focus of our analysis was, what values are being centered when elaborating and assessing solutions? Sometimes these values (or axiological dimensions) were entangled with how people were being constructed in relation to one another. For instance, when considering profit as a value, participants might be primarily orienting to store owners and their employees. At other times, participants were considering the wellbeing of employees and why employees might be quitting (e.g., are they getting paid enough or are they being mistreated?). Sometimes we see a set of values that get frequently called up together, for example, profit and efficiency. Other times, we see certain values that are regularly pitted against one another, for example, maximizing profit and ensuring fair wages for employees.

Lastly, we conceptualized these four analytical foci NOT as four distinct dimensions, but as deeply interconnected, such as in a network map. For example, if participants are centering efficiency as a value, that might be influencing how they're constructing the cast of characters (e.g., workers as cogs in a machine). They might be considering the relationality between some actors (e.g., employer and employee), but at the same time backgrounding others (e.g., customers). In the analysis that follows, we intend to show how these themes weave together within a subset of focal segments. What we present below is not an exhaustive representation of our analyses, but rather illustrations of common "co-occurrences" that play out across the data. We organize the data according to the dimension of "solution type" to streamline the presentation of our analyses and because it was the most locally stable of our themes.

Data and results

Technological solutions

The first category of solutions we consider are centered on the implementation of technological innovations. Like Dr. Gupta [10], we found that students typically began their brainstorming with technological solutions. For example, almost all groups suggested installing self-checkout machines within the first few minutes of conversation. The groups considered these solutions in several varied ways. In one version of this solution, self-checkout lines are suggested without attending to the context of the problem:

Segment 1

Serena: My initial reaction is like, um have more checkout lines, right? But that would really only work if we paid people more [...]

Malik: I had an idea of...self-checkout lines, sort of like in Target. I just feel like they're very useful and will help a lot of people who do not really have to see a cashier. So we can just make the lines shorter. *[Interview: M+S+J+M; Lines: 39-40, 49-55]*

This segment, occurring immediately after the introduction of the prompt and with minimal elaboration, illustrates a student offering a technological solution without explicitly considering specifics about the store environment (e.g., how the “small” size of the store might limit space for new checkout machines and line). Rather than contextualize the solution with information from the prompt, the students apply their experiences of big-box stores (in this case, Target) to the store in question, assuming what works in a corporate context will also work in a small neighborhood grocery store. Explicit comparisons to large corporations like Target, Walmart, or Amazon were common with this type of solution. Malik’s use of the word “just” downplays the complexity of the problem and suggests that he views this solution as a “quick fix.” Furthermore, Malik’s suggestion to add self-checkout lines came a few turns after Serena raised the concern that adding more checkout lines would require hiring and paying more cashiers. In this way, self-checkout becomes a solution to the store’s potential cash flow issues. Across the set of interviews, it was common for students to orient to self-checkout as a solution for high labor costs, but without deep interrogation of the types of startup and maintenance costs and human oversight required for operating these machines.

In another version of this solution, which also occurred immediately after the prompt was given, Dustin suggests a technological intervention and incorporates aspects of context from the prompt, which his partner Harveen expands upon:

Segment 2

Dustin: Well, the first thing that comes to mind is, uh, self-checkout...but then also, we have to keep in mind that they’re low income, and some people, you know, pay with cash that might not be recognized by [the machine] because it’s dirty, or sometimes they might need help scanning the items or might not know how to use technology. So that definitely makes it difficult to implement...

Harveen: Yeah that was definitely my first thought. Um like pretty much every store I can think of has self-checkout now. Um, I know like recently like my Costco just got self-checkout and it’s like a store where it’s like big items and like some of those things cost like, two, three hundred dollars. So it’s like, I don’t know, it’s like, they still trust their customers to like not steal or anything, so that was something that also came to mind. I don’t know how to explain...but basically I don’t want them to think that, just because these are low income people that they will be stealing. Like that’s never a good thought, I guess. But um I know in my like the Walmart near my house, I guess, like a good area so their like checkout lines it’s like, there’s never anyone watching. But if you go to the like one like near the city...they have two three people watching the checkout line, everything is locked up, like nail polish which is like a dollar, two dollars, everything is locked up. So I feel like, that’s just kind of like a line that they have to kind of watch. Like I don’t want them to be policing the self-checkout line I guess. *[I: D+H; Lines: 48-96]*

Again, the first idea raised in the students’ brainstorming is a self-checkout system. Unlike the previous example, however, the students in this group attend to some of the context from the prompt: that the store is in a “low-income neighborhood,” although the ways in which Dustin

and Harveen take up this context differ. In his initial proposal, Dustin's focus is on potential deficits of the customers, specifically the assumption that they will be technologically illiterate ("[they] might not know how to use technology") or might be paying with dirty cash. Dustin positions these deficits as the primary obstacle to successfully utilizing this solution, making it "difficult to implement," rather than positioning the solution itself as not well-suited for the context. Like Dustin, Harveen's first idea is also self-checkout, which she has seen modeled by big-box stores like Costco and Walmart. However, perhaps reacting to Dustin's deficit framing of low-income customers, Harveen anticipates and heads off another deficit narrative—that people in a low-income neighborhood are likely to steal if not monitored (an idea that came up several times throughout our data set in concurrence with self-checkout systems). Grounding it in her experiences of stores that appear to trust their customers and stores that don't, Harveen identifies the ways in which a highly untrusting store can send dehumanizing messages to customers, for instance, by locking up even low-cost items like nail polish. She makes an explicit value-judgment about this behavior, stating, "I don't want them to be policing the self-checkout line." This example illustrates how highly technological solutions can cue up deficit-based assumptions about low-income community members, but also provide opportunities, at times, for students to challenge these assumptions.

Another example of a technological solution followed by a more nuanced attention to context occurred later in Malik and Serena's interview, while the group was discussing using trackers for the retention of grocery carts that the store might loan out to help urban customers without cars get their groceries home:

Segment 3

Malik: I do like the lend-a-cart idea, and I also do like the idea about having trackers on it. Just because I know people are sometimes lazy and they just leave it anywhere after they're done unpacking, and I feel like having at least, [Joanna nods in agreement] some accountability, or like [Serena nods in agreement] quote-un-quote punishment, for that would be, fine. Sort of like, um the first time you just leave a cart where it's not supposed to be you get like a warning. Second time, maybe you can't come for like a week or something [Serena nods in agreement]. But just something to have accountability to that so like, um the store wouldn't lose money like just buying more carts and over and over again. So I do like the idea.

Serena: I like that um especially since like you said the store like wouldn't lose money, especially since it's like a small grocery store. It's like, again we still don't really know the size if it's like, I don't like a Target grocery section size or if it's like a mom-and-pop thing. If it's like a mom-and-pop situation, then you really don't want them to be like losing money by replacing carts. But people would still need a way to get their groceries home. *[I: M+S+J+M; L: 400-424]*

Like Dustin in Segment 2, Malik falls into deficit reasoning about the customers in the community, not only assuming that customers will be "lazy" if entrusted with shopping carts, but also begins considering putative measures, including banning customers from the store after a second strike. He proposes "punishment," and suggests putting trackers on carts, an idea he

elaborates on later with the suggestion of auto-locking wheels and location-triggered alarms. His assumptions about the untrustworthiness of customers not only necessitates high-tech security interventions but pre-supposes the need for punishment. In doing so, the focus of the conversation shifts from innovating in order to meet a need in the community to policing the community through technology. As with the deficit narratives of technologically illiterate customers, this dehumanizing narrative of lazy and untrustworthy customers centers the value of profit for the store over the needs of the community. Serena re-contextualizes Malik's point by applying the low-income context not to the customers, but to the store itself, distinguishing between a Target-like store and a "mom and pop" shop. She acknowledges that, in the latter instance, it is important that the store not lose money through potential property loss, but underscores the fact that even so, "people would still need a way to get their groceries home." She draws out a nuance in the conversation that was previously lacking, acknowledging both the needs of the store and the customer without focusing on assumed deficits of people in low-income communities.

These segments demonstrate the regularity with which students' first attempts at solution generation imitate technologies they've seen implemented in big-box stores such as Target or Walmart, a trend which persists across the data set. While they often start at the same place, the variation in how students evaluate technological solutions by orienting to multiple values at once (e.g., profit and/or human welfare) at times create openings for challenging deficit assumptions. In many cases, however, values centering profit are tightly coupled with technological solutions, and tend to co-occur with dehumanizing narratives, showing that attempts to cue up an orientation to social inequities in the prompt (e.g., by layering in a "low-income neighborhood" context) does not necessarily lead to liberatory thinking. The variation in value focus (here, profit and/or human welfare) arose across the data set in other technological solutions discussed as well, which included ordering groceries through an app or website, and carts with built in scanners.

Human resource management solutions

The second category of solutions we consider is human resource management solutions, which focus on altering or controlling the movement and behaviors of people who work and shop at the store. In one such example, Harveen and Dustin appear to foreground the comfort and happiness of employees, but do so in service of efficiency, productivity, and employee retention:

Segment 4

Harveen: I guess like- when I'm thinking about stores that handled the pandemic really well like ALDI comes to mind. I feel like ALDI like, those workers, I don't know man. I don't know where they get their training, but they will scan everything in like a minute... Something I've seen on like Twitter recently is like, letting cashiers sit down...like, if there's happier employees like they can like, I don't know, up the pay a little bit, let them sit down, just train them to kind of like get through everything quickly, and like they reduce like the stress of like stocking stuff. Like basically if they just have happier employees they'll work faster, and they'll get the job done easier so like the lines aren't

piling up? So I guess maybe instead of like moving the customers around we try to like help the employees be better at their job.

Dustin: Kinda like the Chick-fil-A of the supermarket. (Harveen: Yes!) It's like really, really good management. I know that Chick-fil-A, what makes them so good is they have just a boatload of workers, but they have infrastructure for these workers to do really set tasks...it's really specific and planned out. I'm not sure how well you can do that in a grocery store, but if you have, you know, set plans for each employee with more predictable stuff to do, then it might make the job easier. But yeah definitely making the job easier will not only help the current employees, but make new jobs more appealing to the people who might be looking for work. *[I: D+H; L: 225-253, 258-263]*

Drawing from ideas they've seen implemented by large corporations, like ALDI, Harveen and Dustin consider whether better trained and "happier" employees would make checkout lines move more quickly. While they appear to be centering the wellbeing of employees by paying them more, "letting" them sit, and reducing some stressors, the concern for their happiness and wellbeing is wrapped up in efficiency narratives, suggesting that the employees' comfort and happiness is only valuable if it leads to speedier checkouts. When Harveen suggests refocusing their efforts on helping "the employees be better at their job," what it means to do a good job in this context is almost entirely based on speed and efficiency of work output, rather than other metrics like customer engagement and satisfaction, or identifying and solving problems. Dustin takes this a step further and suggests that implementing an assembly line model, like he's seen at Chick-fil-A, where employees are given "set tasks" and "more predictable stuff to do," would not only increase efficiency and productivity by making the tasks easier but it might make the job more desirable to current and future employees. This notion is fueled by assumptions that grocery store workers do not desire autonomy or complexity in their work, and positions them as cogs in a machine. Dustin and Harveen take for granted that processes that work for large corporations like ALDI and Chick-fil-A will work in the small neighborhood store. Within this limited socio-technical imaginary, Dustin and Harveen foreground values of speed and efficiency have dehumanizing effects on some actors, like employees, whose needs only get considered in relation to their work output.

In another example, Serena, Malik, and Joanna consider sectioning off the store so that high-risk employees can fulfill grocery orders with less risk of exposure to COVID-19:

Segment 5

Serena: I feel like there's kind of a second problem like within the first one, which is just like, there are now people like in the neighborhood who were employed there who can't work there anymore, because of employer policies and the underlying health conditions. So maybe if they had like the reservation system [where customers sign up for a time to pick up pre-orders] they could have a section of the store that's like just supplies, it's like closed off, and then they could rehire some of the people to work in that section where they wouldn't be interacting with the customers and they just be like packaging the goods, you know?

Malik: Yeah I didn't think about that, but I actually really do like the idea, just because it allows for the store to have actually the same amount of capacity of customers but it's just splitting up the workforce based on preference. So like, if you don't feel like talking or working with people, you can just switch out with somebody and go back there, just to pack up the goods, leave it out in the back door of the store or something, cars come by, pick up the bags, and just go. So yeah, I feel like that does solve both problems actually, in a pretty efficient manner. Yeah.

Joanna: Yeah I think that definitely utilizes like more employees and resources better, and like [considers issues related to] COVID. *[I: M+S+J+M; L: 127-159]*

In contrast to the previous example where efficiency is the primary value foregrounded, Serena, Malik, and Joanna also begin to foreground the health and wellness of high-risk employees who the problem states, “had to quit because of employer policies and/or underlying health conditions.” Serena identifies these employees as “people in the neighborhood,” marking a connection between the store and the people living in the community where it’s located. However, when Malik evaluates the solution based on its efficiency and foregrounds the store’s need to maintain customer capacity, employees get positioned as interchangeable (“you can just switch out with somebody”) and high-risk employees’ health needs get reframed as “preferences” about whether they “feel like talking or working with people.”

Furthermore, when Joanna agrees that the solution “utilizes like more employees and resources better,” her language positions employees as objects, whose health needs matter primarily because of the store’s need to retain employees. While this solution is not explicitly modeled after solutions implemented in big-box stores and layers in some features of context, like the impact of the COVID-19 pandemic on frontline workers, some features are also highly abstracted and detached from the realities of a small neighborhood store. With employees’ safety conceptualized only in terms of limiting their interactions with customers, it limits the potential for meaningful social relations that are characteristic of a small neighborhood store. We see in this example that centering values like the health and wellbeing of frontline workers has the potential to support more socially expansive orientations, but foregrounding values of efficiency quickly subsumes actors in the language of managerialism [6], which reduces people to the value they provide based on the work they produce.

Other common human resource management solutions across this data set include limiting the paths customers can take or goods they can access so they can be streamlined in and out of the store more efficiently, moving the checkout lines outside where there is considerably less risk of COVID-19 spread, and limiting customer entry into the store. Similar to what we saw with technological approaches, there was some variation in how students evaluated their solutions, due to the diversity of ways they layered in context and oriented to different values. While these solutions, at times, came closer to opening up access to more expansive socio-technical imaginaries, the focus on human resource management tended to cue up narratives of managerialism [6], which had a dehumanizing effect on actors who were often constructed in relation to their work output (re: employees) or as needing to be controlled (re: customers).

Human welfare approaches to solutions

The third category of solutions we consider are human welfare approaches, which tend to foreground values of human rights and capabilities (e.g., [28]). In one example of a human welfare approach, after being asked by the facilitator “what might you want to know or want to learn in order to understand this problem and to go about solving it?” students start to disaggregate the idea of a low-income community into different types of populations and contexts that may require different solutions:

Segment 6

Malik: I'm also kind of curious about how big the grocery store is, because in a way I do kind of- like when I hear small grocery store, I think of like the corner store or something like that, something really small. I don't think that's the case here but, I would like to know how big it is. And if they do have the resources to like say, hey you do marketing and go make a website and if they know how to do that, and then, just because sometimes low income neighborhoods don't really use the Internet that much and they don't have the know how to actually like create a website. So I guess the demographic in general is really important.

Serena: No, I definitely agree like with the Internet one. My grandparents live in like a really small rural town...and my grandparents don't even have dial up Internet. Like, they live like in the country country...so they would not appreciate a system as much as someplace else where they had to go book everything online.

Malik: In that case, would it be better to revise the entire idea based off the demographic? Cause like if it's, a small grocery store in like the city, I'm not gonna say I assume like they all have Internet but like, I would assume like they kind of know about the Internet, how to like go to websites and stuff like that. But if it's like in a case like Serena said, in the rural areas and they don't, I guess know the Internet that well, maybe maybe that's not the best option for them. *[I: M+S+J+M; L: 188-233]*

While Malik's first questions here seem to be leading to more deficit narratives about technologically illiterate people in low-income communities, Serena quickly grounds his thinking in the personal experience of her grandparents in a rural community. Between his questions and her experience, they come to realize that it would be “better to revise the entire idea based off the demographic,” acknowledging the fact that low-income communities are not monolithic and have diverse needs depending on their context and makeup. This sets the group up to start brainstorming variations on the idea they were discussing (pre-ordering groceries) with adaptations for both rural and urban neighborhoods. In doing so, the neighborhood's status as low-income shifts from a deficit that limits the solution space to contextual information that expands it.

In another example of a human welfare approach, Harveen considers the STS thinker skill “locating power in systems” [15]:

Segment 7

Harveen: I guess maybe like locating powers in systems. I guess this class in STS last semester, we really thought about like who's oppressed and who's marginalized and like who has the power and I feel like that really gave me like an epiphany like 'whoa like we live, we live in a society' [laughing] like...there's always someone in power, always someone being oppressed and I feel like as someone that, like very rarely is oppressed, like, I feel like that privilege kind of like makes me forget that there are people that don't have it as good as I do. So um, I guess if we are able to find people that like are oppressed and marginalized and like the people that do have the power, we can cater to those that don't have the same privileges so like we could kind of like help out those people that might need to like do layaway. Like maybe if they could pay off their groceries later like we could help those people out. We could help those that are working from like these odd hours, we could help moms that don't have people to watch their kids while they're shopping. So like if we could have like someone that's like watching their kids...if we can think about all those people that have extenuating circumstances, I feel like that might make our solution a bit more comprehensive I guess. *[I: D+H; L: 797-827]*

Here we see that Harveen begins to focus on the larger system in which the store is embedded (“it just kind of made me like have an epiphany like 'whoa like we live, we live in a society'”), where a broader array of stakeholders’ interests and needs become visible. She notes that her own position of privilege can often function to make the experiences of others who may be marginalized or oppressed harder for her to see. By rhetorically juxtaposing people “in power” and people who are “oppressed,” she implies that there is a relationship between the two, in which the people who are in power may have some culpability in the oppression of those who are marginalized, and thus they also have a responsibility to mitigate it. When talking about the responsibility of those in power to help those who are marginalized, she includes herself as occupying some dimensions of power; using the word *we*, she says, “the people that do have the power, *we* can cater to those that don't have the same privileges so like *we* could kind of like help out those people that might need it.”

After establishing her own and society’s responsibility to support people who are marginalized, Harveen proceeds to layer in some particularities, elaborating the context to specify who those people might be and what they might need. She elaborates on particular needs coupled with potential solutions, like offering a layaway program and childcare, which center the lives and needs of customers in their own right, not just to maximize the store’s profit at the customers’ expense. Despite de-emphasizing values of profit and efficiency, Harveen frames these more expansive imaginaries, in which the store is viewed as part of a larger system, as still satisfying the store’s needs by making their other solution “a bit more comprehensive.” Finally, while Harveen does set up a stark dichotomy between people who have privilege/power and people who are marginalized, notably, she does not draw on deficit narratives when elaborating on the needs of hypothetical low-income customers. Instead, she describes them as “people that have extenuating circumstances,” which positions “low income” as a situated phenomenon rather than an individual trait.

In another example, Serena, Malik, and Joanna explore a relational model of power and responsibility, which diverges from a simplistic hierarchical model, in which the store alone has power over customers and employees:

Segment 8

Serena: Yeah, I also feel like there would be- there's, like Joanna was saying, I feel like it's not even just like the manager of the store it's also the responsibility of the customers, or just, just as humans to like, care about the other people, you know? Enough not to get them sick.

Malik: So, I'm just like looking at the STS thinker skills, and, one thing that sticks out to me is like locating power in systems. So in this case, I guess, would the power be divided between both the customers and the workplace to keep each other safe? Or would it still like mainly be centered around uh the store and like the employees, the people in power to actually like I guess regulate all that. Just a question.

Joanna: Uhh I guess it's how you look at it? Cuz like, if you look more at like the employees, it would obviously be more like the power chain. Like yeah and then, I guess if you look more in like a community kind of way then, I guess everyone has the power to not get people sick. So that would- yeah, I think it just depends on the perspective.

Serena: I agree. I think slightly more of the power like rests on like the institut- like not even like the ground level employees, but like the people who like are making the decisions about how the store is run...but I guess that also it still- you know, depends on how big the small store is you know, like some small businesses don't have like an upper-level person. The person who like owns and started the business is still like working on like you know, employee level. [I: M+S+J+M; L: 874-924]

In examples of human resource management approaches, where actors tended to be cast in relation to the store's or management's needs, concerns about employee's health functioned primarily to ensure that the store could continue operating at full capacity. In this example, however, students center human health and safety from values of mutual care. Instead of viewing the power and responsibility for keeping people safe as limited to one particular actor (usually, the store owner or management) and others as powerless, Serena, revoicing Joanna, offers a distributed model of power and responsibility, in which "it's also the responsibility of the customers, or just, just as humans to like care about the other people." Malik relates this idea back to the STS thinker skill, "locating power in systems" [15] and raises the possibility that while power is distributed in the store, it might not be distributed evenly across actors, and the people who have the power to create and enforce policies and regulations may have some additional responsibilities to keep others safe.

Joanna responds that it "depends on the perspective": If they consider actors in a vacuum, then the power relations that tend to get foregrounded may be more hierarchical, but if they look at the community as a whole, "everyone has the power to not get people sick." Attending deeply to

the context of small stores, Serena further breaks down assumptions about the boundaries between management and employees, noting that it “depends on how big the small store is you know, like some small businesses don't have like an upper-level person, the person who like owned and started the business is still like working on [an] employee level.” Here, Serena and others draw on a relationally and socially expansive imaginary of the store as a space where community members (including store owners/management and employees) have a responsibility to care for one another, which contrasts starkly with models of big-box stores, where power hierarchies, social detachment, and for-profit values limit the imagination to a set of social relations that are highly exploitative and extractive.

In another example, Dustin and Harveen discuss the STS thinker skill “looking for ethics in artifacts” [15] and focus on the artifact of paystubs. Drawing from her own experience working an hourly job, Harveen recalls:

Segment 9

Harveen: I remember like, um, so like on our like paystubs or whatever, it would have like how many hours you worked, like overtime, like what you're getting paid for the first forty hours like what you're getting paid afterwards. I feel like that might be a really good thing to look at like, we know all these workers are quitting but it's just kind of like why are they quitting? Like, they're low income, it's a pandemic, they know that if they quit they're not going to get another job, so it's kind of like, we kind of have to think about like, okay they're quitting, there must be a problem with the employer. So it's like if we're able to look at the pay stub and see like 'Oh, these people are only getting paid like \$7.25' like, that would be a really good indicator...so, if we're able to kind of like advocate for the employees rather than just the grocery store, we might be able to help retain those employees. And maybe we if we could look into like what benefits they have like, I don't know as someone who has only had one job, getting that one job took forever. There was so much paperwork so much stuff so I can't imagine being someone that would quit it just because, like it's a lot of work [to find a new job]...So like I feel like if we're able to find out why these people are quitting, it might help with keeping good employees, keeping the lines down, and keeping people going through this system. So I feel like fixing the employee problem might fix our other problems. *[I: D+H; L: 1014-1058]*

Instead of just viewing employees and their needs based on the work output and value they provide to the store, Harveen uses the paystub as an artifact to interrogate why employees might be quitting when they know it will be *even more work* to find another job during a pandemic. She considers that “if we're able to kind of like advocate for the employees, rather than just the grocery store we might be able to help retain those employees,” suggesting that their default has largely been advocating for the grocery store. Drawing on her own experiences and difficulties securing a job and agonizing over whether to quit it, she identifies with the employees’ plight; if they are quitting *en masse*, there might be something about their working conditions or compensation that is driving them to quit. Rather than framing employees as interchangeable and easily replaceable, an experience she remembered having herself as an employee, she frames them as worth retaining and supporting. This observation propels the conversation away from the

narrow confines of the store context into a more systems-oriented consideration of the impacts that a lack of livable wages and social services have on people's lives.

They begin to discuss Universal Basic Income, and the impacts it could have on people's lives. Harveen says:

Segment 10

Harveen: I feel like there should be, like a little bit of transition for people that are like low income. Like, I don't know, I feel like many people stay low income because they're-I don't know, they have those benefits and it's like, those benefits are kind of keeping them afloat, but they know if they if they, I don't know, go back to school and they're getting a nursing degree or something like they get their CNA, and they're going to be right above that threshold, they're not going to have that support anymore, even though they need it. So I feel like if we are able to increase that threshold...it'll help people stay afloat no matter what, but also push people to better themselves like whether that's like staying at home to help their family or getting a better job. Like, I don't know that's such a good idea, because I don't like the idea of keeping people down just I don't know. Like so many low-income families are staying low income because they know they can't afford to go up almost like they know they can't afford \$200 a month for healthcare so it's like, they (Dustin: Yeah) kind of just have to stay- like there's no middle ground anymore. *[I: D+H; L: 1127-1159]*

Harveen points to how (at least in the US) social services are only provided to people below a certain income level. However, this threshold is quite low, and the fact that there are no services to help people "transition" to marginally higher income levels incentivizes people to stay in low-income jobs because they cannot afford to lose access to basic services and human rights like healthcare and childcare. This, in turn, discourages people from doing things "to better themselves" and their communities, like working in higher paying jobs, going back to school, or staying home to take care of their families. On a societal level, this lack of support makes upward mobility almost impossible, because "there's no middle ground anymore." Harveen considers some solutions to this problem, like "increase that threshold...\$2,000 a month" to "help people stay afloat, no matter what" and transitional support for social services. This more socially, economically, and politically expansive imaginary extends far beyond the store and maps out a future in which society and systems of government support individuals' basic rights to financial security [28] and access to upward mobility rather than "keeping people down." In this imagined world, people can spend their energies engaged in life-giving work (whatever that looks like to them) rather than just trying to survive. Here, we see Harveen concerned about the wellbeing of people and society and sees the store's employees as a microcosm of the broader social and political landscape.

In contrast to the technological and human resource management approaches, human welfare approaches tended to be more socially, economically, politically, and relationally expansive (though not always all at once), which resulted in more systems-level thinking and provided more diverse entry points for problem solving. In many examples, students "zoomed out" from the store as the primary system of inquiry and instead used it as a lens to examine broader

societal structures. They offered a wide range of solutions, sometimes targeting the store and sometimes focused on broader issues, like political reform. These more expansive imaginaries diverged from big-box store conceptualizations and focused instead on layering in and deeply interrogating contextual features of the small, low-income community store. They supported more asset-based and relational constructions of actors and entertained a wide range of human-centered values.

Discussion

Our analyses attending to “co-occurrences” of four analytical foci: (1) solution type, (2) store context, (3) construction of people, and (4) values—revealed some patterns across the set of interviews. We describe some insights that these patterns made visible below:

Conceptualizations of a “low-income neighborhood”

Across focus groups, we see negative characterizations of people in low-income communities that align with both engineering specific understandings of the public as identified in Lambrinidou and Canney [5], and society-wide biases about poor people [42]. Several characterizations of public commonly found in core engineering documents [5] emerged in students’ reasoning, such as the public being “technologically illiterate” (as Dustin asserts in Segment 1: “we have to keep in mind that they’re low income and some people... might not know how to use technology”) and the public “lacking/desiring technologies” (with Malik assuming in Segment 6: “low income neighborhoods don’t really use the internet”). While Lambrinidou and Canney [5] observed that these traits were applied to “the public” in general and not low-income communities specifically, “poor” was the most frequently occurring characterizations they identified in engineers’ understanding of the public, suggesting the clustering of traits we’ve identified here as being tacitly present in more general engineering contexts.

The impact of correlating “low-income” to lack of knowledge or access to technology in students’ design work is twofold: First, it positions the community engineers’ work aims to serve as intellectual inferior, distancing the engineer from the impact of their work in a way mirrored by the use of pronouns in some cases (e.g. using “we” to refer to themselves and store owners at times, and “they” to refer to customers or employees). Second, by defining the potential customers as unknowledgeable with regards to technology, design solutions can be shielded from scrutiny, as the blame is placed not on the solution for failing to meet the needs of the community, but on the community for not understanding how to utilize the solution. This can be seen when Dustin says in Segment 1: “So [customer’s lack of tech-savviness] definitely makes [self-checkout] difficult to implement, but there might be some sort of way.” In this example and several others across the data set, the assumed deficits of the customers is cited as the barrier in implementing the solution, rather than determining the solution to be unsuited for the scenario. Through this logic, the suggestion to imitate big-box stores’ use of high-tech systems (in Dustin’s case, self-checkout machines) is presented as practical, with the only flaw being the technologically illiterate customers who will be its users.

In a less common, but potentially more concerning pattern, we see students characterize people in low-income communities as lazy and/or untrustworthy in their design work, in line with cultural myths about poor people [42]. This generally arose in the context of needing additional security for various technologically focused solutions, such as with self-checkout machines, or as in Segment 3 where Malik describes the need for trackers, and later, alarms, or auto locking wheels on shopping carts because “people are sometimes lazy and they just leave [carts] anywhere.” Again, the assumed deficits of low-income people are presented as challenges to be overcome through technological interventions. These dehumanizing assumptions go a step further than distancing engineers from the communities they serve by opening the door to policing and putative treatment in the design process, a line of thinking which can easily lead to direct harm.

It is heartening, then, to see that as [41] describes, student reasoning around socio-technical issues was not “stable or belief-like,” but was rather highly dynamic and context-dependent. We see this dynamic thinking in Segment 6 where Malik, after falling into deficit narratives of lazy and untrustworthy poor people, begins to inquire into the demographics of the neighborhood. These questions create openings for a more nuanced conceptualization of a “low-income neighborhood” that varies with context, and subsequently, in needs, grounded by Serena’s personal experience with rural towns. Similarly, Dustin’s deficit narratives in Segment 2 are challenged by Harveen, who uses her personal experience of highly surveilled grocery stores to push back on the idea that low-income customers are likely to steal. In both groups, students’ reasoning moves between narrow (deficit-based) and more expansive (asset-based) conceptualizations of low-income people several times in the discussion, indicating the potential for breaking free of harmful stereotypes in design work.

In a final example, Harveen’s discussion of the factors that prevent upward economic mobility in Segments 9 and 10 illustrates a consideration not only of features of the community context, but of the broader social and economic forces responsible for the existence of the low-income community to begin with. These segments set the stage for an even more expansive discussion about economic inequality in the U.S. While Dustin and Harveen’s discussion extends beyond the scope of the grocery store in the prompt—focusing on customers’ childcare needs, dangers of over-policing customers, and Universal Basic Income—their attention to human welfare creates opportunities for their design work to ‘break free’ from the narrow and harmful narratives recruited earlier in their conversation, shifting their focus from solely generating profit for the store owner to considering the well-being of all parties involved.

Across the examples of negative characterizations of low-income communities (being technologically illiterate, lacking technology, being untrustworthy/lazy), there are several commonalities along our four thematic foci. In all instances, these harmful narratives arise in the context of highly technocentric solutions. Generally, these solutions foreground the goal of generating profit for the store owner, either by increasing efficiency or minimizing loss, and anything that compromises profit-generation (like the anticipation of stealing customers) gets cast as a threat to the store. Finally, these examples tend to cast low-income customers as barriers to the design process, rather than the ultimate beneficiary of the design. The implicit ideology that connects these ways of thinking is one that positions the responsibility of engineers as

making money for a business owner through technological interventions, i.e., a highly capitalistic and technocratic stance.

While some co-occurrences illustrated locally stable and potentially harmful assumptions about low-income communities, others demonstrated productive and expansive reasoning around socio-technical issues. Interestingly, while the examples containing deficit-narratives about low-income people demonstrated relative consistency in solution type, values, context, and stakeholder construction, examples where students attended to the low-income aspect of the prompt in non-deficit ways exhibited significant variation. They considered the interests of a range of stakeholders, not limited to the store owner, but including customers and employees, and subsequently attended to more values than pure profit. In their variation, examples foregrounding asset-based characterizations of low income people stand in stark contrast to the relatively homogenous thinking that surrounds deficit-based characterizations, and demonstrate a significantly broadened imaginary with respect to the solution space; rather than fall into pre-established technocratic goals, methods, and narratives, the students illustrate a diversity of thinking and an attention to public welfare that modern engineering problems so desperately need.

Ideologies underlying “narrow” reasoning and openings for “expansive” reasoning

Across our data set, we observed socio-technical narrowness in some of the ways the literature described, i.e., as constrained by ideologies of technocracy and neoliberal capitalism (e.g., [2], [6]). For instance, in most of the interviews we conducted, large corporations and the solutions they implemented dominated students’ imaginations and their subsequent design work. While many students did have experiences with small neighborhood stores, students’ storytelling about these experiences tended not to come up until later in the interviews, after they had already considered common solutions implemented by big-box stores. Sometimes, students used big-box stores to legitimize and justify the implementation of technologies and human resource management solutions, reasoning that if they work for successful stores like Walmart and Target, they would likely work for any other store (like in Segment 1 when Malik considers implementing self-checkout lines “sort of like in Target”). Other times, large corporations were propped up as innovators and their innovations were viewed as unproblematically good (like in Segment 4 when Dustin and Harveen celebrate the ways ALDI and Chick-fil-A streamline and standardize employees’ work processes).

Drawing on the socio-technical imaginaries of large corporations had implications for the ways students imagined social relations operated within the store, and for the social futures they made available to various stakeholders. Within these narrow social imaginaries, technological and human resource management solutions commonly co-occurred with values of profit, efficiency, and productivity as well as with abstracted accounts or dehumanizing narratives of actors (like in Segment 3 when Malik conceptualized low-income customers as “lazy” or in Segment 4 when Dustin conceptualized employees as cogs in a machine). In these cases, even when students appeared, on the surface, to consider the needs of employees and customers, those needs were often subsumed within the store owner/manager’s needs. For instance, in Segment 4, when Dustin and Harveen modeled their solutions after those implemented by Aldi and Chick-fil-A, they drew on a limited socio-technical imaginary in which employees’ happiness is only valued

because it leads to employee retention and more efficient/productive work processes. The notion that employees' happiness can be a value in itself was not accessible at this moment, not because students don't hold that belief, but because the corporate, neoliberal capitalist systems that dominated their imaginations orient to workers as commodities, not as whole human beings.

Despite the similarities we found between our data set and socio-technical narrowness described in engineering education and STS scholarship, we also found examples of "narrowness" that exhibited more complexity than elaborated in the literature. For instance, we often saw students orienting to a more expansive set of values (e.g., efficiency, profit, human health, employee happiness) in evaluating a technologically or socially narrow set of solutions. While the presence of these values provided some openings for critique of deficit assumptions, these critiques rarely got fully realized without a more substantive shift that foregrounded human welfare values. Sometimes, this happened though the introduction of specificities or particularities which served to support ideological expansiveness. For instance, in Segment 9, when Harveen introduces the pay stub as an artifact to examine why employees might be quitting, it opens up different dimensions for analysis, like political, economic, and social dimensions. Using the pay stub as a lens, Harveen and Dustin consider the store and employees as part of a broader socio-political system, and they begin to reason about how implementing policies like Universal Basic Income might change the lives of low-income workers. This more "expansive" socio-technical imaginary opened up the possibility for solutions that centered values of human-welfare and oriented to actors as whole human beings.

Very rarely, we noticed that students displayed skepticism or strong critique about whether simple solutions even existed to solve such complex problems that spanned multiple intersecting systems. This perhaps represents a fourth category of solution-approach, not represented in this paper, in which students reject the 'game' of offering solutions and instead engage in societal critique. In one such interview, Kalim and Jordan (pseudonyms) observe:

Kalim: Well, first of all, people in the store they're like frontline workers. They're the most exposed to you know the virus, so they might be experiencing lots of things without even getting a virus. Like my family we go to like this Asian grocery store that's like, it's a pretty small store. And, like the family that runs the store- like everybody in the store ended up getting COVID. And then the Father, sort of the Patriarch, passed away. So this is like a very real issue... I don't know like with these conditions if it's really that simple to find a solution for this. [...]

Jordan: I guess with the idea of capitalism, it just makes me think of like, everyone is disposable. You know, it's cheaper to replace you than to stick with you and to fight for you. So um, yeah, you know, that's why I feel like, you know, the shift to technology has really been accelerated. It's cheaper to have a machine and you know, you maintain the machine than it is to have an actual human support, and you know, trying to care for their needs. *[I: K+J, L: 123-133, 820-833]*

This excerpt shows that students' deep critique of technocracy and capitalism in design work is possible but may leave students feeling like solution-generation is difficult. As educators, we need to expand our imaginaries of students' engineering design work to include societal critique

as a legitimate outcome, even if it seems to circumvent the generation of solutions in the short-term. If we want to support more robust connections between students' personal and professional senses of responsibility, we must be prepared to approach students as whole human beings, who deserve educational experiences that honor their experiences and offer emotional as well as intellectual support for making sense of a complex and unjust world.

Next steps and concluding remarks

While our analytical approach in this work focused on modeling co-occurrences of salient themes, we have already begun to see the influence of "pivots," or key discursive moves, in supporting a shift from one line of reasoning to another. These pivots, which can be initiated by facilitators or students, can function as potential openings to more expansive thinking and attention to human welfare. Examples in our data set of facilitator-initiated pivots include asking students what additional information they would want to know to solve the problem (which preceded students' disaggregation of low-income communities in Segment 6) and prompting students to consider STS thinker skills (which elicits Harveen's discussions of power and ethics in Segments 7 and 9, respectively) [15]. Student-initiated pivots, while subtler than facilitator-initiated pivots, occurred in varying forms. A student grounding the conversation in personal stories often led to more nuanced attention to context, such as Serena's discussion of her family in a small rural town in Segment 6. Additionally, we see instances of students directly critiquing their peers' application of deficit narratives leading to more welfare-oriented thinking, like Harveen's pushback to Dustin's assumptions in Segment 2. While this preliminary analysis of pivots is not yet robust enough to draw larger conclusions, our work in this paper lays the groundwork for further exploration of pivots and the role of facilitation and contestation in socio-technical thinking in the future.

Finally, while this work identifies ways in which potentially harmful technocratic thinking can occur in students' problem solving, it is important to clarify that the use of technology does not necessitate a technocratic ideology. Though many of the students' technocentric solutions co-occurred with deficit narratives of the public and capitalistic values of profit, we believe technologies can be recruited for human welfare goals. Nazar [43] identifies one instance of liberatory, technological design work in the efforts of a 7th grade student who, with the use of his own lived experiences, community collaboration, and technical knowledge of coding, created an app that helps victims of bullying avoid potentially dangerous areas. In illustrating this possibility for "busting out" of co-occurrences like those we find in this work, Nazar emphasizes the need for STEM education to create opportunities for new forms of design work and the expansion of "what counts as engineering." As such, we understand the technocentric reasoning we see in this work as just one of many possible versions of socio-technical thinking and believe we can move towards an engineering education in which human-centered design works with, rather than against, technology.

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