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The Sociotechnical Divide is Emotional: Affective Interventions in Learning Spaces for Socio-Technical Integration

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Introduction

Place and *space* as a node of intervention to bridge the socio-technical divide has recently received attention in the engineering education literature. In these studies, place and space are an important factor in developing a sense of belonging among engineering students and faculty; this can be operationalized in efforts to contest elements of engineering culture that reinforce the socio-technical divide, e.g. barriers that make it difficult for first generation college students, people of color, LGBTQ+, women, people with disabilities, and people from low income settings to stay in engineering (Reedy and Tomblin 2024; Salm, Zacharias, and Cicek 2025). These papers posit that some elements of space and place lend themselves to change (e.g. creating more study spaces, images of people from a range of cultures, classrooms that don't reinforce the banking model of education, etc.), thus supporting initial steps toward the betterment of engineering culture. This may be a constructive intermediary step towards culture change, rather than directly taking on obdurate socio-structural and cultural elements long embedded in engineering culture (e.g., socio-technical dualism, meritocracy, depoliticization, see Cech 2014). Ultimately, altering undesirable and oppressive cultural elements of space and place can provide immediate change and a bridge to more substantial cultural reforms that will require many years to take hold (Secules 2023).

Our results come from a yearlong project at a large R1 university that explored the use of Science and Technology Studies (STS) tools to build interdisciplinary relationships among faculty and undergraduate students from engineering, social sciences, and humanities backgrounds (York and Conley 2020; Reddy et al. 2023). As part of that project, we held workshops in spaces designed to increase interactions and connections among participants, with the goal of developing course modules that integrate content and tools from engineering, humanities, and the social sciences. Workshops and subsequent gatherings were designed to cultivate an affective environment of comfort and vulnerability to help break down disciplinary barriers. In this paper, affect theory serves as a guide for crossing the socio-technical divide through space and place (Anderson 2014), allowing us to explore how our interventions influenced people's comfort and vulnerability.

We aim to make several connections that are rarely covered in the engineering education research literature related to understanding and intervening in the socio-technical divide. First, since feeling like you belong is inherently affective (Kerr and Garforth 2016), we need to understand the affective conditions of engineering spaces and places. Second, since barriers to a sense of belonging in engineering education are in part a consequence of the socio-technical

divide, we need to pay attention to how spaces reproduce affective environments (Rodrigues and Cicek 2024). Third, we want to show, through an experimental study, that altering the affective elements of space and place can lead to cultural change that increases people's ability to be comfortable and vulnerable, thus increasing their feelings of belonging.

Engineering Culture, Learning Infrastructure, Space, and Affect

Undergraduate engineering education has generally used the banking model of education—professors standing at the front of the room as the authority on and purveyor of all useful knowledge (Friere 1970) -- to the detriment of students. The banking model is unconcerned with giving students agency in their own education (Tomblin et al. 2024). A prevalent engineering mindset that reinforces the banking model is the *uncritical acceptance of authority* (Riley 2008). This mindset is reinforced by rigid plans of study and an intense dedication to decontextualized problem solving (Downey 2005; Leydens and Lucena 2018). Even though most work on the *culture of disengagement* in engineering education does not explicitly address the role of the banking model in this phenomenon (Riley 2008; Cech 2014; Cicek and Rodrigues 2024; Ozkan 2025), cultural elements of engineering such as meritocracy, depoliticization, social-technical dualism, and fealty to militarism all are easier to transmit and maintain through the banking model, as opposed to more de-centralized models of education (Tomblin et al. 2024). While the socio-technical divide is maintained through social processes baked into engineering culture, the management of space and place is underappreciated for its role in maintaining this divide (Reedy and Tomblin 2024; Salm et al. 2025).

How we use space for learning is not foreign to educators. For example, early childhood educators in the Reggio Emilia tradition have been using spatial arrangements to communicate a sense of belonging since the late 1940s (Deguara 2025). However, after the first grade in the U.S. K-12 educational system, most spaces are designed for rows of chairs facing the instructor at the front of the room. In the 1990s, Henri Lefebvre's (1991) *Social Production of Space* gave serious attention to the role of space in university education. His analysis attended to ways that the socio-material nature of space is socially constructed by stakeholders with goals in mind about the user experience of space. These goals hold political content that dictate behavior and can also be acted upon by the users of the space. Lefebvre believed that these goals influence how education is conducted. In his estimation, the design of most classrooms had the effect of separating the thinking (the mind) from the embodiment of everyday practices and activities (the body) - how the body realizes and acts on new knowledge. Significantly we think, he asks, "can we re-educate bodies for space?" (Lefebvre 2014: 34 in Middleton 2017). We take this to mean that we should be noticing the impact, positive or negative, that the space in which we learn is having on our bodies and the role our bodies and all their sensory capacities play in learning.

Lefebvre's work formulates the problem as such: in most university settings, educators attempt to educate the mind and not the body (and its sensory pathways). This posture tragically ignores critical elements of learning and ways of knowing. As a corrective, we should consider additional elements of space: how does space regulate movement, gesture, smell, taste, sound, touch, and moods (Middleton 2017)? Lefebvre's work challenges the education research community to make visible the way spatial design and arrangements, including mundane material objects of the room (like furniture, blackboards, podiums, objects of study, demonstrations, and so on), influence educational practices, pedagogy, and learning. He is asking researchers not to focus solely on the mind, but the body and its needs as well. His work sparked a movement within education to develop a research agenda focused on learning spaces that focus not only on mind, but on bodies and their needs (e.g., Middleton 2017; Rands and Gansemer-Topf 2017).

In engineering education research the socio-materiality of space framework shows us two ways learning is affected: by material objects in the classroom and the arrangement of learning spaces (e.g., lecture halls with a podium up front). The way materials shape learning technical concepts has a longer history of being studied than actual spaces (e.g., Pea 1993; Johri 2011; 2012). Studies like these highlight the situatedness of the material aspects of education, emphasizing both the social and material nature of education (Johri 2011). This research has helped us think about how the use and arrangement of materials in the classroom can influence who feels they belong in technical spaces (Secules et al. 2023).

Whether a space is welcoming and open to diverse viewpoints has implications for breaking down the socio-technical divide. More recent studies of space and place in engineering schools have focused on how factors such as symbols and architecture (of a classroom, study spaces, labs, gathering spaces, hallways, maker spaces, etc) influence a sense of belonging. Technical spaces can be hostile toward non-technical thinking (Riley 2008; Cech 2013) and what are deemed non-masculine identities and underrepresented groups (Faulkner 2000; 2015; Rulifson and Bielefeldt 2017). *Technical narrowness* in particular makes it difficult for perspectives from lay people, non-Western ways of knowing, the humanities, and social social sciences to enter into engineering discourse and classrooms (Cicek and Rodrigues 2025). For example, Salm and colleagues (2025) identified five ways spaces can detract from a sense of belonging: Tokenism (symbolic representation of minorities without addressing systemic inequalities), Emptiness (spaces that don't support collaboration), Left-over Culture (unremoved symbols and artifacts from the past that don't align with current student aesthetics and values), Disparity of Care (spaces in disrepair and neglect), and Inconsistency of Space (lack of design coherence). The collective presence of these arrangements can cause students to feel discomfort, stress, and alienation.

While not specifically a study of space, Conley and colleagues (2022) description of the STS Futures Lab at James Madison University exemplifies a space designed to level the playing field among students of different disciplines (STEM, social sciences, and humanities) and faculty and students. The lab is filled with student-created artifacts and populated with furniture and whiteboards that can be arranged to facilitate collaboration among students and faculty. This encourages STEM students to practice socio-technical systems thinking and has empowered STEM students in cross-disciplinary collaborations with STEM and non-STEM faculty (York and Conley 2020). With efforts such as the STS Futures Lab in mind, and Lefebvre's conjecture that students need to "re-educate their bodies about space" we turn now to affect theory to better grasp why spatial arrangements are so important to explore.

All spaces have an affective condition that sets the moods and emotional atmospheres that influence the outcomes of events (Anderson 2014). As Lefebvre (1991) asserted, awareness of emotional reactions to space and the ways that the body feels in space is somewhat invisible to most of us because we haven't been trained to notice. This thinking aligns with work in STS on infrastructure where society is mostly unaware of how it shapes what we do until it breaks (Star and Ruhleder 1996). However, one way of revealing the politics of infrastructure (or the materiality of space in general) and new ways of knowing about infrastructure, is to pay attention to its affective dimensions. We all can sense how infrastructure feels or the environmental mood it creates if we pay attention to it (i.e., Nye 1994; Michaels 2020; Heatherington and Jalbert 2023). Applying this to learning spaces, a type of infrastructure itself, we can see the potential benefits of understanding the affective conditions of learning spaces.

Research into the role of affect in engineering education is relatively new. Given that exploring the social dimensions of engineering, including the moods and emotional atmospheres engineering spaces produce, is discouraged in engineering education, this is not surprising. Rodrigues and Cicek (2024) speculate on the importance of understanding and harnessing the role of emotion in developing the competencies of socio-technical systems thinking. Here, the idea is that if students can make emotional connections with stakeholders, they can better understand the people and systems they will potentially design or improve, especially when providing students with opportunities to work with communities and get a feel for the spaces they work in (Smith et al. 2021; Reynante 2021). Godwin and colleagues (2017) posit that the affective disposition of historically marginalized students toward their experiences in engineering education is an important consideration when tackling issues of retention. Others have begun to explore the ways care manifests in engineering education (Stettler Kleine et al. 2022), which has implications for how we might arrange our spaces to exhibit care (Salm et al. 2025). Mogul and Tomblin (2022) experiment with ways to integrate student understanding of the role of emotions, sensory pathways, interoception, proprioception (body awareness in space), and movement to expand the number of knowledge inputs for socio-technical systems

thinking. All of this work either implicitly or explicitly helps move us toward a better understanding of how affect plays a role in engineering, but none of this work explicitly speaks to the affective conditions of space, perhaps one of the most underappreciated potential interventions for bridging the socio-technical divide (Secules et al. 2023; Reedy and Tomblin 2024; Salm et al. 2025).

Theoretical Framework: Affective Conditions of Learning Spaces

A focus on sociality, at the cost of understanding how the material world influences us, limits comprehension of how we can alter obdurate aspects of culture or social structures (Marres 2012; Whatmore and Landstrom 2011). Much of the current engineering education research, including the formative works of Cech (2013; 2014), Riley (2011), Leydens and Lucena (2017) and others that have shown us the effects of the socio-technical divide, meritocracy, and depoliticization on engineering culture, have focused on the socio-cultural aspects of engineering (Reedy and Tomblin 2024). However, the role of the physical and material aspects of engineering learning spaces have recently garnered more attention in an attempt to bring together the social and material elements of engineering education as a place of intervention (Secules et al. 2023). This is because spaces are socially constructed by educational administrative decision-makers, which means they can be reconfigured to produce different results (Calabrese Barton and Tan 2019).

Material arrangements interact with and inform the "different sets of cultural rules, norms, and logic, which make visible different legitimate performances (Secules et al. 2023: 208)." This relationship between space and social structure leads to its inhabitants partaking in affective labor and practices to navigate it (Kerr and Garforth 2016; Branch and Duche 2024). Here we connect affect to the experience of learning spaces. Paying attention to the affective nature of learning spaces is necessary to understand the conditions that create substantive, transformative learning experiences, especially attending to the socio-technical divide where ignoring affect can hide ways to set affective conditions that bridge the divide (empathy, collaboration, vulnerability, comfort with others, comfort with discomfort, struggling together, moving together, care) while at the same time reinforcing affective conditions (competition, depolitization, technical narrowness, lack of care, cultural disengagement) that reinforce the divide.

The experimental workshop presented in this paper provides opportunities for understanding how setting certain affective conditions can exploit the cracks in institutional structures that reinforce the socio-technical divide and disciplinary siloes. We are looking into how experimentally-designed affective conditions (the workshop) can energize interdisciplinarity

through conditions that make “radical” agency permissible (breaking down the socio-technical divide or simply disciplinary divides/siloes, Taylor et al. 2010).

The notion of sense of belonging is a good place to start because it is an important affective condition to encourage when attempting to cross disciplinary divides or the socio-technical divide in general. Smolka and colleagues (2020) show that socio-technical integration work among social scientists and technical disciplines produces anxiety and bouts of “imposter syndrome” that need recognition and acceptance for successful collaborations. Furthermore, nurturing a sense of belonging has increasingly become important when rectifying underrepresented group participation in a host of engineering practices that include undergraduate education curriculum, life-long learning, collaboration, design showcases, competitions, celebratory social events, and so on (e.g., Hess et al. 2025). These practices have strong affective connections, as they all occur in spaces and places that intentionally and unintentionally create an affect, moods, and emotional atmospheres that influence the outcomes of events. However, to say more about the connection between a sense of belonging and space we need to understand how affect mediates space and nurturing a sense of belonging.

Michel Foucault (2008) describes governance structures that regulate the affective capacities of human bodies and emotions using the concept of *apparatus* (Anderson 2014). Apparatuses can have a positive or negative valence (or both) in how they affect human bodies. In our project, the interdisciplinary workshop was intended to be a counter to some of the oppressive aspects of standard educational (banking model) and disciplinary practices (e.g., siloes, departmental norms, U.S. educational system norms, peer review, competitive grants, tenure, etc. Different apparatuses create different affective conditions for participants to encounter experiences (new and old) and opportunities to learn from and with others.

We draw inspiration from experimental workshops that explore how affective conditions can inhibit or facilitate desired outcomes when exploring socio-technical integration work in laboratory spaces (Smolka et al. 2020; Davies 2021). We created a workshop (counter-apparatus) as a modest counter to the dominant apparatuses (Freire 1970; Lefebvre 1991) in higher education that prevent substantive exchange among STEM, humanities, social sciences, and other fields. Our workshop used material manipulatives and arrangements that aimed to create an atmosphere of collaboration, cooperation, willingness to help, empowerment, indeterminism, uncertainty, care, acceptance, conjecture, willingness to be helped, and vulnerability that are generally counter to the culture of disengagement reinforced by typical engineering learning and research spaces. We expected that participants would bring their affective experiences shaped by departments, programs, university policy, tenure, acquiring grants, non-university work obligations, classroom standards, and family life that could produce

undesirable affective atmospheres such as the specters of standardization, authority, deficit thinking, determinism, outcome orientation, oversimplification, certainty, individualism, a focus on success (or what that looks like beforehand). During the workshop and subsequent interactions, we observed faculty and undergraduates from a variety of fields encountering these tensions as they struggled to create interdisciplinary modules for engineering, humanities, and social science courses.

Methods

Description of Workshop

We conducted an experimental two-day workshop in August 2023 designed to develop interdisciplinary course modules in STEM, humanities, and social science courses. It was held in The Loft, a studio space within the Edward St. John Learning and Teaching Center at the University of Maryland College Park, featuring open space, movable furniture with a variety of tables and chairs, a kitchenette, rolling whiteboards, and prototyping supplies. Faculty and Undergraduate Research Fellows (URF) engaged in interdisciplinary collaboration and knowledge exchange with a variety of interactive activities designed to help participants feel comfortable with each other and exchange knowledge, but also to feel comfortable in situations of vulnerability (e.g., not knowing the language and content of other disciplines; faculty/student power asymmetries, etc.). The experiment continued on after the two-day workshop, with faculty and URFs meeting several times afterwards to continue designing interdisciplinary modules, followed up with a module test session, faculty implementation of the modules in their courses, and a final debrief focus group. We outline the basic structure of the workshop below, but other relevant details appear in the results section.

The first day began with a presentation on project goals and STS concepts related to socio-technical systems thinking relevant to the workshop. Beyond the space itself, the first affective intervention of space as a way of creating place was a stoke (which we define as a warmup with thematic connections to learning goals) that explored the frustrations of understanding disciplinary jargon across disciplines. Each faculty was then paired with an URF. For the rest of that morning we facilitated two activities: *Seeking Scholarship* and *Boundary Object Formation*. In the first, faculty-student pairs would select a topic the professors were familiar with and then find scholarly work on the topic from another discipline, discuss the presence of jargon. In the second, they brainstormed a list of boundary objects (a common object to all disciplines that facilitates exchange of knowledge, ideas, and information from diverse perspectives - see Star 2010) and how they are situated within the topic using whiteboards to facilitate everyone's participation through movement. At the end, groups shared findings and discussed relevancy to knowledge formation and social issues. Then workshop participants had a shared meal

prepared by the workshop organizers. After lunch, engineering and non-engineering faculty were paired to review, question, comment, and discover a common boundary object in each other's course syllabi. The first day ended with all participants seated in a circle, discussing and reflecting on experiences and learnings from the day.

The second day began with a Creative Anticipatory Ethical Reasoning (CAER) activity, an upstream engagement activity that asks participants to create plausible future scenarios through design fiction to reveal potential societal issues related to the implementation of emerging technologies into society (York and Conley 2020). Participants practiced working together on a socio-technical integration project from the perspective of each participant's respective discipline. We formed two teams, each consisting of at least one engineering and one non-engineer faculty and URFs, and were given a workspace with a table and chairs so they could face each other, movable whiteboards for sharing and recording ideas, and prototyping supplies for designing a physical artifact that might be used in the future. After selecting a physical artifact (a boundary object) that had relationships with everyone's discipline as a team, societal driver cards (created from Dumit's (2014) influential article) were used to surface socio-technical aspects of the artifact.

During the design fiction exercise, each team created a hypothetical future scenario, and discussed how it would change the sociotechnical implications of the chosen artifact. Groups were asked to identify relevant stakeholders, activities, and other artifacts, as well as consequences and modifications to the selected artifact that would be relevant in the hypothetical future. These findings were shared on rolling whiteboards. Participants used prototyping supplies to produce models of the chosen artifact and its corresponding socio-technical system. Each group shared their prototype (and their socio-technical struggles) with the other group. Groups easily moved from each other's work stations. Although the CAER activity took most of the second day, it was broken up with another shared meal where workshop participants informally shared their perspectives on the workshop. The last activity of the second day saw faculty pairs and URFs work together to propose preliminary course modules that they would eventually build, in collaboration with each other.

Data Collection/ Participants

The participants were two engineering faculty, three non-engineering faculty (policy, student affairs, and business), and seven undergraduates (in engineering, policy, landscape architecture, information studies, computer science, and business), and four co-organizers/co-PIs on the project. We recruited faculty participants based on being able to make pairs between STEM and non-STEM disciplines. Most faculty participants had previous familiarity with the

workshop organizers, but also had not directly worked with them. We selected faculty that had limited experience with socio-technical integration work, the field of STS, and ethics courses. URFs were selected based on similar criteria, and we encouraged faculty participants to recruit undergraduates they knew. Beyond working with faculty participants on their course modules, the URFs also had data collection and analysis roles on the project. URFs performed participant observations during the workshop and, at the conclusion of each day, wrote memos to reflect on their experiences. Written reflections were collected from faculty participants, who were also interviewed before the workshop and at the end of the project. URFs and workshop organizers also collected notes from each subsequent faculty meeting and held a focus group at the end of the project to debrief the faculty on their experiences. URFs wrote memos about their experiences throughout the project.

Analysis

Data analysis generally followed a modified grounded theory approach (Timmerans and Tavory 2012) whereby we started with general questions about how the workshop design encouraged and presented challenges to interdisciplinary outcomes. This approach resulted in three rounds of coding that led to new and more refined coding categories. One of these rounds produced the coding categories we used to explore the role of *affect* in the workshop and subsequent aspects of the project. Based on student memos and audio transcripts collected during the workshops, interviews, meetings, presentations, and group debriefs, URFs and PIs independently coded for recurring themes in the experiences of different participants. URFs and PIs gathered periodically in hybrid meetings to validate each person's independent analysis. We presented our analyses to each other and discussed commonalities and differences between found themes until we agreed on which themes to include in the codebook. After deciding on an initial set of themes, students re-coded transcript data based on the agreed upon codebook. In subsequent meetings, URFs and PIs would present vignettes to demonstrate salient codes and create diagrams to model how codes conceptually worked together. One of the most salient themes that emerged from these exercises was the tension between participant comfort and discomfort with various activities of the project. From there, we began to speculate about the role *affect* played in the project. Table 1 lists the codes we used to frame the analysis for this paper: Comfort/Discomfort, Empowerment, Sense of Belonging, and Conflicting Affects.

Table 1 - Codes used to frame the analysis of the affective conditions of the CREATE/STS workshop and subsequent module development.

Codes	Definitions with Examples
Counter - Apparatuses	CREATE/STS project (workshop) norms that create affective conditions. Examples: collaboration, cooperation, willingness to help, empowerment, indeterminism, uncertainty, care, opinions, conjecture, willingness to be helped, vulnerability, etc.
Institutional Apparatus	Participant external institutional affective conditions (normative experiences) that compete with workshop affective conditions. Examples: departments, programs, university policy, tenure, acquiring grants, non-university work obligations, family life), which produce a multiplicity of affects that interact with the norms/goals of CREATE/STS: standardization, authority, deficit thinking, determinism, outcome oriented, oversimplification, certainty, individualism, success oriented thinking, student/teacher divide, siloedness, faculty hierarchy, etc.
Comfort	Any action or interaction that results in people feeling more comfortable and trusting. It is a move toward being vulnerable to others in the group.
Discomfort	Any action or interaction that results in people feeling discomfort. This can be intentional or unintentional. For the purposes of the CREATE/STS project, intentionally introducing situations that challenge existing mindsets and predispositions is desirable in order to nudge people into exploring new mindsets, practices, and knowledge domains. Unintentional discomfort can also arise from the CREATE/STS project, such as people feeling like they have failed or aren't meeting project expectations (e.g., lament, frustration, shame, etc.).
Self Awareness	Instances where people gain self-awareness as a result of reflections and experiences associated with the CREATE/STS project.
Empowerment	Instances where people feel empowered (a growth in self-agency) as a result of reflections and experiences associated with the CREATE/STS project.
Sense of Belonging	Feeling like you have found a group of "like-minded" people that have similar goals and aspirations as it relates to socio-technical integration.
Conflicting Affects	Examples of where conflicting affects emerge in the data. This may be

	assessed once all coding is complete, but might be found in tensions with each other in participant statements. Examples include productivity vs. cooperation; determinism vs. indeterminism; care for others vs. individualism, fact vs. opinion/conjecture, standard vs. non-standard, homogeneity vs. multiplicity (heterogeneity), etc.

Experimenting with Affective Conditions that Encourage Crossing the Socio-technical Divide

Space and how it is arranged matters when crossing the socio-technical divide (Calvert 2023). Key to understanding the affective conditions within the space of the workshop is discussing how it differs from traditional learning spaces (ones that reinforce the banking model of education, e.g., lecture rooms, meeting spaces with set furniture, etc.). We call what was experimental and changeable about the space, manipulatives: elements of the project, physical or otherwise, that were selected, altered, cultured, or interacted with to nurture interdisciplinary behaviors that are necessary for bridging the socio-technical divide. While our goal always involved providing activities and environment that would help people be comfortable and vulnerable with each other, it is only after we analyzed the data that we began understanding these changes as creating an affective condition that would create vulnerability through comfort, discomfort, empowerment, self-awareness, sense of belonging, and conflicting affects (Table 1). Based on our analysis, we began to understand our process as altering the affective conditions of learning.

Figure 1 conceptualizes the relationships among the three variables manipulated during the workshop: space, artifacts, and people. Interactions among people (physical, communicative, collaborative, etc.) are guided by artifacts of spatial arrangement (rolling couches, whiteboards, tables, etc.) and artifacts to engage with (prototyping supplies, food, etc.). Interactions among people are mediated by the workshop space, arranged in a variety of ways to encourage open and vulnerable collaboration. These open and vulnerable interactions fill the space with a collaborative affective atmosphere, establishing a norm of egalitarian behavior. This further reinforces how people act upon, interact with, and move manipulative artifacts to design new artifacts and tend to physical space, iteratively supporting goals of collaboration.

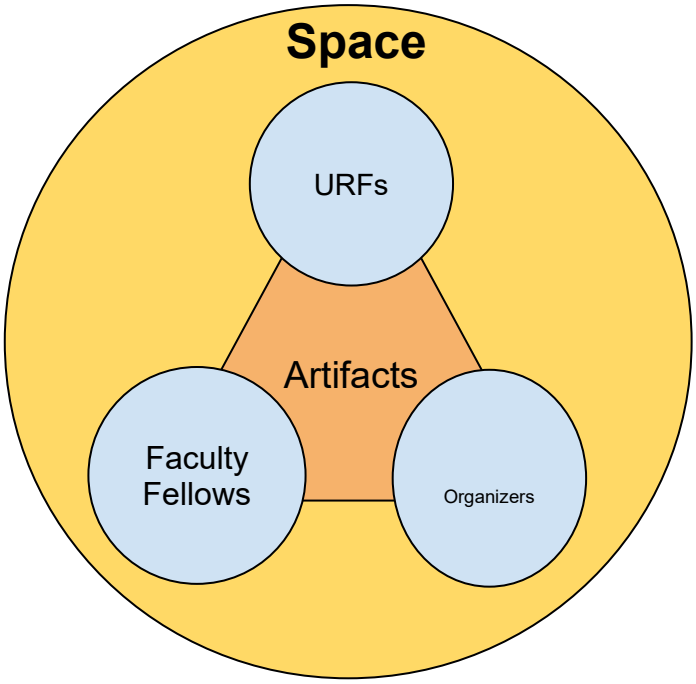

Figure 1 - The relationship among the artifacts within the workshop space (existing and introduced), workshop participants (URFs, Faculty Fellows, Workshop Organizers), and workshop artifacts.

Here we use the example of a workshop meal to describe the ways we used space and materials to build a community of people comfortable with each other so they would let down their disciplinary guards, transcend established and perceived power asymmetries (e.g., STEM vs. humanities; faculty vs. students), and assuage fears about not knowing other participants' fields. Meals are central to any gathering of people and can be used as a space of affective intervention (Figure 3). Here we show that it is important to pay attention to the artifacts of a meal. We decided against using restaurant catering – which tends to produce both food and packaging waste in favor of a home-cooked meal. Our idea was to use real silverware and as many real plates as possible, and prepare food we made at home. This required us to make some logistical leaps (plates and silverware are heavy, food needs to be reheated in only one microwave, etc.), and emotional leaps of our own.

Figure 3 - The home prepared meal shared with the workshop participants on the first day.

It forced us to confront the possibility that we would embarrass ourselves: What if no one liked what we cooked? What if the dish we prepared just didn't turn out well on the day we made it? What if we didn't make enough? The number of ways to second guess ourselves on this was endless. To address this, the PIs (workshop organizers) each chose a dish they were extremely comfortable making, nothing that required them to learn a new recipe, or even a recipe at all! The first author made a Tunisian Stew and the fourth author made pesto and brought in some tomatoes and a loaf of bread. Our leap of faith translated into the affective conditions we had hoped to create. When we sat around the table eating dishes that were inspired by cuisines, what we were able to do was switch on a sense of national pride, continuity with the past, and a recognition and appreciation of each other's familial ties and ancestral origins. It felt like the outer protective layer that our participants normally wear was exchanged for something softer, more relational, joyful, and humble. Participants started volunteering their own family stories – one faculty participant started recounting stories that helped us understand their heritage, background and kinship relationships.

Participant Affective Experiences

We illustrate how the manipulations of space, artifacts, and people led toward a more collaborative affective condition through four examples from the workshop. Each example will emphasize specific codes drawn from Table 1. Even though most of the examples include most elements from the codebook, we limit our emphasis to one or two codes per example to make the analysis easier to follow. The last example (Encountering Old Habits) illustrates some of the challenges of creating collaborative affective conditions.

Stokes: Self Awareness and Empowerment

Besides the layout of the space, the day 1 jargon stoke was the first affective intervention. It helped participants become self-aware and indirectly confront frustrations of understanding jargon across disciplines. All participants, including the workshop conveners (PIs), gathered in open space, standing in a circle that allowed for ease of movement and direct interaction with others. The stoke asked participants to select and present jargon unique to an individual's culture that others in the group probably never heard before. Each person presented their culturally unique jargon accompanied by a gesture. Everyone in the group had to repeat the jargon and gesture until everyone had gone. Once everyone had gone, the whole group had to remember and cycle through the jargon/gesture again together. Another aspect of the stoke asked participants to address each other by first names, a norm that maintained itself through the workshop. This gave permission to the URFs to refer to faculty participants by their first name rather than their titles: professor, doctor. The PIs referred to the faculty participants by their first name as well, which modeled to the URFs that it was appropriate to do so. This brought awareness to and removed the taken-for-granted symbolic power dynamic of titles that is present between undergraduate students and professors, which made the URFs more comfortable being honest and genuine with the faculty participants.

Stokes were instrumental in encouraging participants to be open with each other. While many participants felt that stokes were uncomfortable and awkward, they understood their function. As one URF stated, while they, “did not enjoy them personally, activities such as Stokes were key to starting the progress to more human interactions.” A professor shared this sentiment, stating they “really dislike the social games,” but also “acknowledge its function”. Under these conditions, participants found themselves observing and empathizing with each other's similar behavior. URFs wrote about watching professors showing hesitant behavior “due to uncertainty” and worrying over “doing tasks to requirements.” Awkwardness and discomfort is visible vulnerability; a transformation through self-awareness occurred during the first day while students and faculty empathized with the struggles of the other. One student remarked,

“it was the first time I realized I was in the same position as the teacher participants”, identifying in the “shared role of struggling participant.” Faculty stated similar thoughts:

> “And so [stokes were] definitely making everybody equal, you know, it’s a really great way to make professors realize that there is a different way to engage students. You know, so I think that made a big difference just in terms of culture. …The fact that I was a participant, not a teacher… We were just sitting around in a circle, you know, those little things do matter.”

One engineering faculty, who frequently mentioned trying to integrate more student participation into his course, mused on how their personal discomfort with stokes was “just like all the other engineering students” they had interacted with in outside class spaces. They described feedback from students within courses as “more adversarial", but described students within the workshop as giving “very helpful” feedback they “don't normally get even from… [their] graduate TAs… even when [they] ask them to.” Another professor commented: “I wish I could drag my students out of the classroom and into these meetings,” adding “that we sometimes forget that our students are human, too … as opposed to us being teaching machines and them being learning machines.”

At the end of day one, in the open group reflection, one URF stated they felt professors were now “more human and less professory.” Both faculty and students assimilated the intended affective condition of the stokes, building trust and vulnerability among workshop participants. This exercise also reveals self-awareness of conflicting affects between what students and faculty experience in their everyday educational experiences (formal titles, lecture halls, banking models, departmental rules, etc.) as opposed to the counter norms (cooperation, egalitarian relationships, vulnerability, comfort with discomfort) the workshop was trying to cultivate.

Artifact-Facilitated Knowledge Exchange: Comfort and Discomfort

An atmosphere of familiarity and comfort, alongside focal or environmental manipulatives to orient conversations, can spontaneously generate knowledge exchange across disciplines, breaking past disciplinary divides and natural discomfort.

On day two of the workshop, while engaging with the CAER activity, an URF was amazed by the “smooth, long, passionate conversations” that one team of three professors and two URFs engaged in when speculating about future scenarios. Collaborating while standing around a whiteboard, participants settled into a “passing of narratives,” where “each participant would

share their own narrative while the others listened, and then ask the next person about their own experience." This was a common behavior across groups throughout day two. Several faculty participants used the phrase "bounce off of each other," or "bounce ideas off of each other" in describing these interactions with other fellows in later interviews. Similarly, an URF described an "equal balance of input and intellectual joy at using systems thinking and expanding endlessly on the topic" of sociotechnical aspects of design futures.

Within the other CAER activity team, a similarly animated conversation occurred around place and space. A non-engineering faculty counterpart reflected on "one of the longest conversations" with their group on "how you set up the room" within education spaces. They described the experience as "beyond moving with a degree of comfort, but into a true thought partner," enjoying getting their "hands dirty," and interacting with "physical objects, like creating something together." The workshop was described as "very meta, like we were building community and building relationships and, like, having fun."

Their engineering counterpart described an iterative "feedback and question" loop that was "useful," "fun," and a "valuable experience." They later reflected on the importance of "giving [one]self the space and time to regularly think about" sociotechnical issues, describing "nothing but excitement about learning about how other people think and what their different experiences are." One faculty participant summed up the experience for most participants: space, and activities within space, support interaction and collaboration, which in turn fosters "a culture of camaraderie and respect."

Building Community: Sense of Belonging and Empowerment

Participants described physical space and group sizes as contributing to a sense of belonging. Many of the faculty, whose typical pedagogical interface with students is through standard lecture halls that reinforce the banking model, enjoyed the collaborative nature of the rooms the workshop organizers (PIs) chose. One engineering professor stated, "you find a place to sit down. Now you're part of this group, right? And there's 'no in the way'… You're talking to each other in a group, the table is the group.'"

Another non-engineering faculty remarked on the "purposeful cohort feel… of three of [my group] together." When asked about their biggest takeaways from the project, they described "that purposeful orientation in person. We are doing this, we are getting to know each other." Even though some people might say "it feels a little campy, I feel like in my mind it's necessary to create that sense of cohort and community." This faculty participant stated the project had a "reaffirming" and empowering effect on their mindset around cross-disciplinary work, inspiring

a “greater willingness to collaborate with others.” An engineering faculty participant elaborated on this sentiment in a post-workshop reflection:

> “Working with [the PIs] has been eye-opening in multiple ways. I like the way [they] openly reach out to colleagues across campus and bring them together…I love the way you quickly break the ice among these colleagues through activities such as mutually enjoying the shared research space, mutually appreciating expressions from each other’s cultures, and mutually celebrating interesting recipes.”

This faculty participant connects aspects of the affective environment to interdisciplinary relations. It was “eye-opening” the way “research space,” “culture,” and “interesting recipes" were celebrated, appreciated, and enjoyed. They later discussed how important this was to their approach in “leading interdisciplinary research efforts” outside of the project, believing these affective conditions should be integrated into their own practices in research. They also remarked on the PIs ability to facilitate conversations amongst “diverse viewpoints” within the workshop using “PowerPoint slides as well as physical prompts (e.g., laminated note cards) to guide the discussion.” Usage of physical and activity artifacts was something they wanted to “try to add ... to [their] repertoire of teaching tools,” sharing how they loved “the structured way in which [PIs] shepherd group discussion.”

Ubiquitous amongst faculty participants were learnings surrounding how to cultivate an atmosphere of belonging; many faculty cited this as the most significant takeaway. All participant faculty, throughout interviews, described realizations about the necessity of trying to integrate affective atmospheres into their own research and teaching practices. In doing so, they revitalized a motivation to perform and seek out collaborative efforts, derived from a “hope” and “joy” now that they had a “cohort and community” on campus making similar efforts.

Encountering Old Habits: Conflicting Affects

While cultivation of uncertain and methodologically uncomfortable environments benefited interdisciplinary integration significantly, the same environments can hinder participants that overfocus on trying to achieve success. In some cases, participants showed emotions of exasperation around uncertainty that seemed to indicate a presupposition of parameters of success -- even though these were not stated norms of the workshop within any of the given activities. Faculty participants imported the affective notion of success to the project from their usual institutional contexts or in Foucault’s terms, apparatuses.

Early on in day one, an URF remarked on professors putting forth “constant positive affirmations” and avoiding "criticism" to progress through the syllabus exchange as quickly as possible. They wondered if awkwardness in conversation was in part due to the hierarchical divide in seniority of position. In a later interview, one professor expressed the discomfort of critiquing another person's expertise, stating, “what the heck do I know about STS, or public policy, or something like that.” To him, “it was just awkward to have those conversations,” a reflection of disciplinary siloedness and divides imported from the apparatus of the university. Even as willing participants in a workshop designed as a counter apparatus for knowledge exchange across disciplines, discomfort can override the ability to engage meaningfully, especially early on. On day one especially, one URF felt that “faculty [and] students” were somewhat “[un]willing to single themselves out as someone not in the know or lost on the current task.”

In another example, a participant with experience in prototyping was able to quickly produce and defend aspects of design alongside integration of sociotechnical ideas, reverting back to his own disciplinary norms. According to an URFs account, this participants' skill “halted collaboration” by their “dominance” of knowledge about prototyping. Other group members suggested changes, additions, or issues, but deferred to the faculty participant with expertise in prototyping who then solved all comments quickly without further consultation with the group. This led to a “lack of engagement,” as other members of the group felt unable to significantly contribute. The participants' familiarity and expertise in prototyping recreated a microcosm of the disciplinary divide, where contributors felt unable to comment on or collaborate on a given situation due to a perceived deficit in knowledge, alongside an acquiescence guided by the assumption that letting the expert do their thing would lead to the best product.

These examples illustrate conflicting affects. Workshop participants unconsciously bring rules and norms from their usual disciplinary and institutional contexts (apparatuses) into the workshop. While the affective condition of the workshop was set to counter these norms, past personal experiences and habits are difficult to change. The example of the prototyping expert in particular exemplifies this, but it should be noted that the other group members also brought norms of deference to expertise and discomfort with new knowledge into the engagement.

Discussion

We demonstrated the significance of paying attention to the affective conditions of space to learning and navigating the socio-technical divide. The broad goal of the workshop was to build a community that can make themselves vulnerable and readily accept the difficulty of doing interdisciplinary work between engineering and non-STEM fields. We see the value of Lefebvre’s (2014) question, “can we re-educate bodies for space?” We don’t have a definitive

answer to this question, but we do see evidence of the benefits of considering the whole body along with its emotions and sensory pathway capacities when building collaborative communities. Intentional, well designed, interventions in space and workshop materials creates a contrast to the learning environment we have historically experienced and become "comfortable" with. Certainly, faculty participants were unanimous in their stated joy of interacting and learning, all discussing a necessity to cultivate collaborative spaces and more open relations in the pursuit of interdisciplinarity. Likewise, students shared common surprise at how receptive professors were to collaboration on equal grounds, with many remarking in post project interviews about their enhanced confidence in interacting with faculty in academic spaces.

The analysis shows that participants experienced comfort, discomfort, self-awareness, empowerment, and a sense of belonging as a result of the spatial arrangements of the workshop and the manipulatives associated with workshop activities. We saw the infiltration of the institutional affective conditions (apparatus) that reinforce the banking model of education and siloes into the workshop, creating an environment of conflicting affects that participants were sometimes aware of but often were not. The latter finding is particularly important, because it illustrates the challenges of intervening in dominant paradigms of university education and research. However, we shouldn't let such complexities discourage us. Workshops alone can't change the prevailing trajectory of institutional education and research. But they can provide clues for how we can cultivate environments that nurture a sense of belonging and vulnerability that allows the emotional labor involved with crossing the socio-technical divide. This study demonstrates the importance of understanding and taking into consideration the constraining apparatus that people experience in their daily work lives. This is why building workshops as counter apparatuses is essential to crossing the socio-technical divide.

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