Pedagogical Workshops for Interdisciplinary Trading Zones with Faculty and Students: Insights from an Engineering-focused University

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Introduction

> *We invite participation from faculty who are interested in collaborating with us to build bridges between STEM and humanities and creating new modules for courses to be taught in the spring. The new modules should specifically raise social and ethical questions at the intersection of science and/or technology in society, and the theme for our work is "what is good engineering and science."*

This is an excerpt from an email that two authors of this paper, Elizabeth Reddy and Marie Stettler Kleine, sent out in the summer of 2022. We were excited for the opportunity to invite our colleagues to join us in the project of interdisciplinary engineering education, informed by Science and Technology Studies (or STS). This project was an opportunity to stage playful workshops and facilitate conversations we did not often get to have, all designed to stimulate interdisciplinary reflections on what we do and why we do it. We were informed by theories of "trading zones" from STS and theories of the classroom drawn from critical feminist pedagogy. We also drew on lively conversations about what it might look like to bring insights from these fields together and put them into practice. While much data remain to be collected and analyzed, we write here to describe the project and to explore preliminary insights it has generated.

In the 2022-2023 year, we recruited a total of fifteen Fellows: six members of faculty and nine students at Colorado School of Mines (or "Mines") to participate in a yearlong sequence of pedagogy-focused meetings and workshops. These efforts followed a similar series of activities at James Madison University the year prior. Supported by funding from the National Science Foundation, our multi-institution research team developed these workshops with the goal of facilitating interdisciplinarity between STEM and humanities, arts, and social science faculty. This project, called the Collaborative Research and Education Architecture for Transformative Engagement with STS (or CREATE/STS), has been in development for some time. The first year of activities took place at James Madison University, a university with an R2 designation in the Mid-Atlantic region of the United States with full-fledged colleges of science and engineering, health and behavioral studies, and arts and letters. In addition, there is robust attention to fostering interdisciplinary work. In 2022, we took the activities to Mines, a small university in the Mountain West of the United States with an R1 designation focused on engineering and applied science. In fact, most educators trained in humanities, arts, and social sciences work in a single department.

We planned these activities in response to significant recent interest in pedagogies inflected by STS for engineering students [1, 2, 3]. Such efforts are often strongly interdisciplinary, crossing boundaries between engineering and humanities fields. There are some signs that engineering education, on the whole, considers interdisciplinary education to be useful for students: evidence of these considerations include ABET criteria [4], curricular and co-curricular requirements of engineering degrees, and pedagogical activities in which different disciplinary knowledges support the integration of "sociotechnical" themes [5, 6].

While pedagogical interest in interdisciplinarity may be strong in the United States [7], we note that it remains easier for faculty, even those most interested in pedagogical innovation, to stay within their "disciplinary silos," in relative isolation from people outside of their own disciplines. Whether we are in the physical and biological sciences, engineering, humanities, or social sciences, many of us find it easier to work and think with those who are trained in fields like our own—not to mention physically encounter them on our campuses or at our conferences. With those people, we share languages, reference points, teaching traditions, and sometimes even foundational ideas about how the world works. While the notion that STEM, humanities, arts and social science fields constitute wholly different cultures [8] has many problems [9, 10, 11], we nonetheless recognize that some kinds of interdisciplinary conversation and collaboration are easier than others. We also recognize that those collaborations that are most strongly interdisciplinary – like those developed between STEM and humanities, arts, and social sciences faculty– may be particularly difficult and yet may drive truly novel and interesting work in the classroom. Further, highly structured courses like those required by traditional engineering programs can leave little space for students to reflect on their personal relationship to what they are learning, such as the alignment of their own values and identity with the technical goals of the program or its larger social implications. These social and humanistic concerns are often explicitly devalued material because it falls outside of what engineering programs understand to be their disciplinary scope (see, for example [12]).

Critical pedagogies developed in the context of humanistic and social studies instruction aim to empower students by encouraging thoughtful consideration of the purpose of their education and the skills they need to develop through it to enact a future they desire. Such approaches often encourage students to draw on their own experiences to deepen their understanding of the topics they are learning and their relevance to their own lives and goals. Feminist approaches seek to "create pedagogical situations which 'empower' students, demystify canonical knowledges, and clarify…relations of domination" [13] while aware that our best efforts to do so are often informed by the very ideas we hope to undermine.

We designed the CREATE/STS project within and as a response to these conditions, drawing on STS theories to understand what Peter Galison has called "trading zones" —that is, places where scholars trained in what may often seem like incommensurable fields can communicate and collaborate across disciplinary boundaries [14]—and produce them in ways that meaningfully include students and encourage faculty and students alike to reflect on interdisciplinarity and engineering education. Practically, we planned to create these trading zones through a series of interdisciplinary encounters designed to support faculty efforts to build modules "infused" with ideas and materials borrowed from participants of other disciplines (as in [15, 16]). Recent conversations about putting STS into critical practice through "making and doing" led us to think about how insights from that field might guide events and frame conversations [17, 18]. At Mines, we recruited participants interested in building such modules with the call to explore "what is good engineering and science" because Mines pedagogically centers around these engineering topics, regardless of department. We thought that faculty and students with training in multiple disciplines might feel intrigued by its implications and empowered to contribute meaningfully to related discussions.

In the following paper, we will describe the project, its participants, and a series of activities including three interdisciplinary workshops held at Mines in fall 2022 and spring 2023:

- STIR (Socio-Technical Integration Research)
- CAER (Collaborative Anticipatory Ethical Reasoning)
- Pedagogical Planning and Feedback

We will then showcase preliminary insights related to these activities. Analyzing interviews with Faculty and Student Fellows involved in this work and observations of workshops and classroom applications will eventually help us understand CREATE/STS activities and their utility and limitations for fostering interdisciplinary pedagogical development as well as achieving broader project goals related to supporting the development of "trading zones" between Faculty Fellows in different disciplines. Even by analyzing just pre-activity interviews with Faculty Fellows and final interviews with Student Fellows, we can build insights related to this engineering-focused context which frames conditions for both the interdisciplinarity pedagogy and the student engagement that we are working to foster. Our findings illustrate that both interdisciplinarity and engagement are limited by the institutional context of engineering education, while also revealing how this kind of work can help students reflect on the limits of a traditional engineering education and consider their own ability to advocate for change**.**

Interdisciplinary Trading Zones In and Through Pedagogy

Our CREATE/STS Project plans drew on the concept of "trading zones" [19], a term that has emerged from Peter Galison's [11] work on how people trained in disciplines which might seem incommensurable can nonetheless overcome fundamental differences in their knowledges and how they approach their projects to bring their insights into alignment. The term "trading zone" references port cities and the ways they might foster communication across cultures, languages, and borders. Other STS scholars have studied how specialists can come to communicate with collaborators with very different training than their own. For example, Collins and Evans describe those who have "gained…fluency" in working across disciplinary boundaries as "interactional experts [20]." Their definition of interactional expertise requires gaining enough fluency in a disciplinary language other than one's own that one can become indistinguishable from an actual trained expert in that field—a high bar, indeed.

Rather than try to facilitate that level of skill, we chose a more modest goal. We conceived of a series of workshops to help Faculty Fellows build what Shannon Conley and Erik Fisher call "interactional competence." Conley and Fisher describe this as a matter of becoming "conversational and knowledgeable to the extent of being able to ask effective questions, engage in ongoing, in-depth conversation with experts, and gain **l**egitimacy" [21]. We designed the activities of the CREATE/STS project to help our Faculty Fellows achieve this competence, guided in part by research that indicates effective cross-disciplinary communication and team skills are supported by experience with shared tasks [22, 23, see 24].

We also reflected on what all potential faculty participants in the project share: interest in working with students. We considered several ways in which bringing students into the project could support the development of our trading zone. In addition to providing a shared value for the participants, we hoped the presence of students, as socially recognized learners and *not*

experts within the community, could create a more accessible "pedagogical commonlands," in the words of anthropologist Marilyn Strathern [25] in which researchers and experts from different fields who might have different research projects, intellectual interests, and methods would be motivated to orient collaboratively towards one another in the shared project of providing an engaging educational experience for the students. The shared value of working with students could not only provide a motivation for engagement but also a communicative lubricant between faculty with disciplinarily diverse expertise.

At the same time, our work in STS on the social practices of knowledge production and transfer brought us to critical feminist pedagogy like that of bell hooks [26]. This scholarship prompts us to see teaching as an opportunity for collaborative knowledge production and identity formation for students and faculty alike. Such an approach runs strongly counter to the 'banking' model of pedagogy that is still powerful in many engineering education programs, in which the faculty knows things and merely needs to transmit this knowledge to the students, whose job is to capture and retain this knowledge [27]. Critical pedagogy seeks to empower students, respecting that students have a stake in what happens in classrooms and that classrooms can be a space for students to learn to contest received models of what school—or other oppressive structures—can be. Because of this, we felt it essential to recruit Student Fellows drawn from populations the Faculty Fellows teach. Student Fellows could provide insight into the value and relevance of the workshops and Faculty Fellow plans and could gain conceptual tools or experience that would support them in engaging with, and interrogating, the conventions of their education. However, our critical feminist pedagogical approach means retaining an awareness that goals of "empowerment" may be simplistic or impossibly ambitious (as in [28]), we must also situate our efforts in pragmatic context of a series of playful activities.

Activities For Faculty and Student Fellows

This project was designed to cultivate conversations that might lead to new interdisciplinary pedagogies informed by interactional competence between Faculty Fellows trained in humanities, arts, and social science on the one hand and Faculty Fellows trained in STEM on the other. Student Fellows were also selected for the project, bringing differently situated but crucial perspectives to bear on the project theme of "what is good engineering and science," on interdisciplinary encounters, on education at Mines.

Mines-based PIs acted as facilitators supporting this work and studying it as it developed. Student Fellows who participated in the project not only took part in workshops, but they also joined us in undertaking research over the course of an academic year 2022-2023.

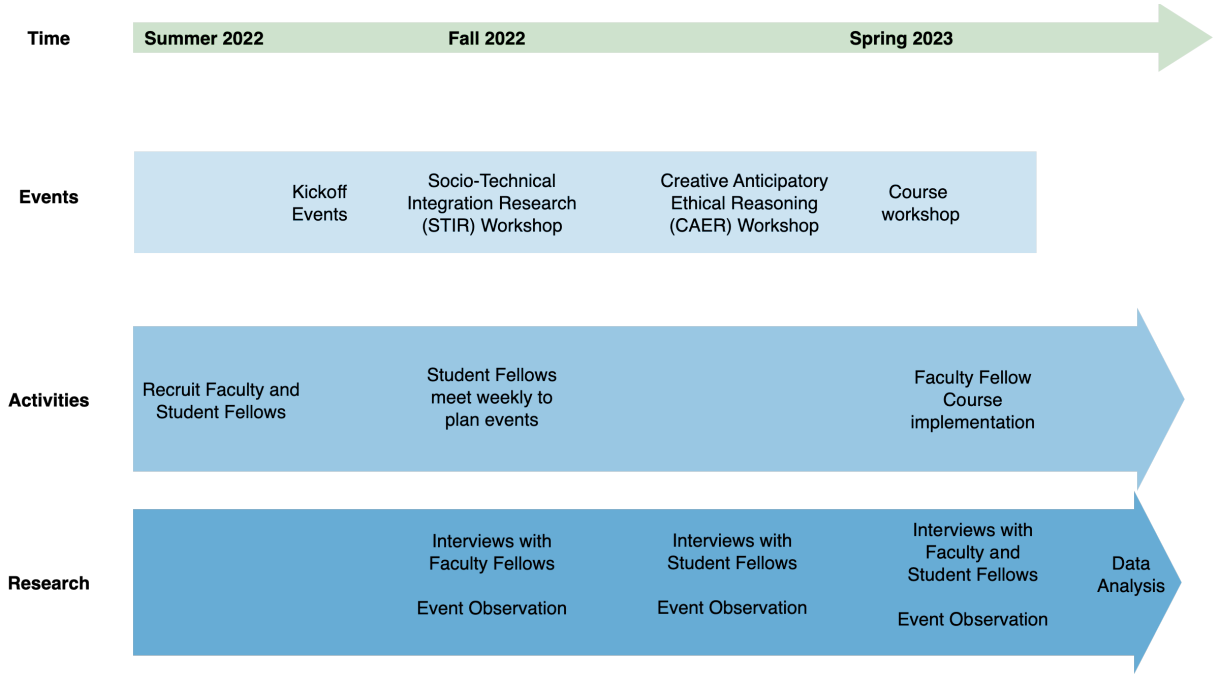


Figure 1. Project flowchart

Recruiting

We described the research project and invited faculty from across the Mines campus to submit expressions of interest.

We sent emails out to a variety of distribution lists to maximize the reach of the call. In these emails, we asked Faculty to identify a spring or summer course they would likely teach in which they could speak to the theme of social and ethical questions at the intersection of science and/or technology in society. We framed the examination of these through the question "what is good engineering and science?"

12 faculty applied and 6 were selected based on the following criteria:

- expressing a willingness and availability to participate in the schedule of workshops and commit to developing a new module for their spring or summer course.
- contributing to a balance of faculty from STEM fields and from humanities, arts, and social science fields, per the CREATE STS model and research goals.
- proposing topics for courses or modules within courses that seemed to have overlaps and compatibilities with each other.

Table 1. Project Fellows

Participants	Status	Departments
Faculty Trained in Engineering and Applied-Science	2 teaching track, 1 tenure track	Quantitative Biosciences and Engineering; Civil and Environmental Engineering; Honors Program
Faculty Trained in Humanities, Arts, and Social Sciences	2 teaching track, 1 tenure track	Humanities, Arts and Social Sciences
Students	8 undergraduate students 1 graduate student	Undergraduate students: 2 Design Engineering; Mechanical Engineering; Geological Engineering; Environmental Engineering; Metallurgical and Materials Engineering; Chemical Engineering; Environmental Chemistry Graduate student: Humanitarian Engineering and Science MSc
Mines PIs	2 tenure track	Engineering, Design, & Society

Each Faculty Fellow selected an undergraduate student to be hired as a Student Fellow in the project. Three additional students (two undergraduates and one graduate) were also hired as Student Fellows. Together, students liaised with faculty, helped plan and facilitate project events, and shared their own perspectives in all group activities. Our participants' professional demographics are outlined above.

Activities and Events

Over the course of Fall 2022, Student Fellows met with us weekly to discuss key concepts and plan events. They met with their individual faculty as needed. Faculty Fellows met four times: first, for a series of kickoff meetings, then for two workshops in which our full team, including Student Fellows and PIs from the three other academic institutions collaborating on this project, participated and shared pedagogical insights. Finally, Faculty Fellows participated in an informal workshop conducted digitally just before Spring semester 2023 to share their course plans and receive feedback.

Socio-Technical Integration Research (STIR)

The first workshop involved a series of activities based on the Socio-Technical Integration Research (STIR) protocol developed by Erik Fisher and team [29]. They developed the STIR protocol to bring STEM researchers and others, particularly scholars in the humanities and social sciences, together to explore the broader ethical, political, social, and legal aspects of scientific decision making in a laboratory context. STIR facilitates "collaborative inquiry between embedded humanists or social scientists and the scientists, engineers and others who host them" [30].

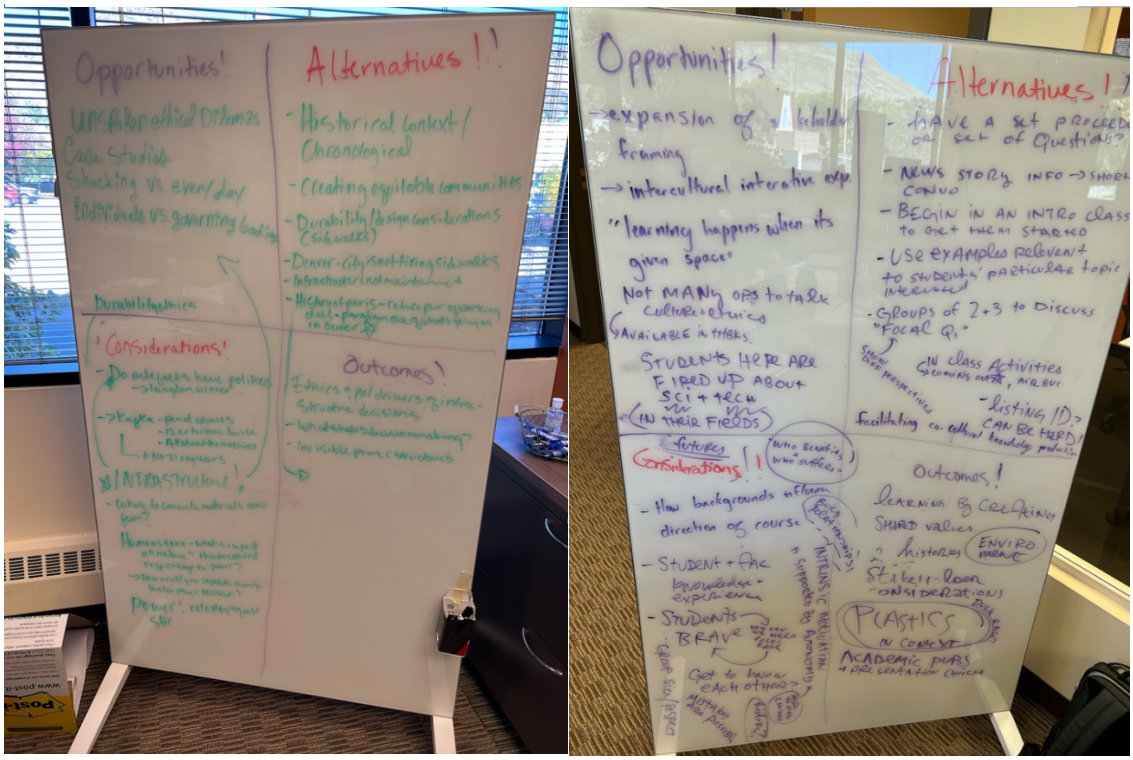
Opportunity	Elaborations/Alternatives
Questions/Considerations	Outcomes

Figure 2. Example of the STIR protocol (developed by Dr. Erik Fisher, modified for the CREATE/STS project

STIR was first adapted for non-laboratory teaching and learning contexts by Shannon Conley starting in the 2014-2015 academic year. STIR has been used in the classroom for a variety of group activities, such as in a module on responsible innovation. STIR was further adapted by project PIs Shannon Conley and Emily York for the CREATE/STS project. In this context, protocol is designed to find opportunities, overlaps, differences, and mutual moments of learning between participants. In preparation for the STIR workshop, Faculty Fellows circulated materials related to their courses so that participants could review them before the event. These included syllabuses, essays, and course maps. After reviewing these materials, Student Fellows and Mines PIs acted as facilitators and created three groups– each with two Faculty Fellows from different disciplines, three Student Fellows, and visiting student and PI faculty facilitators. Two of the Student Fellows in each group had been brought into the project by a Faculty Fellow; the third was unaffiliated with either Faculty Fellow. This was intended to help facilitate the development of interdisciplinary conversations. Mines PIs and Student Fellows spent significant time with this material in advance of the event. With that preparation, Student Fellows took a primary role in prompting conversation, making the workshop space more than just another conversation between faculty.

With support from Mines PIs and visiting faculty facilitators, Student Fellows led Faculty Fellows through a series of brainstorming activities to help them highlight questions, considerations, and spots for elaboration. To show how themes from the workshop could be taken up in pedagogy, one of the CREATE/STS PI team visiting from another university shared a teaching exercise involving improvisation and embodied postures.

Figure 3 and 4. Examples of STIR brainstorms between faculty and students at the STIR workshop



Creative Anticipatory Ethical Reasoning (CAER)

We designed the second workshop event to build on the first STIR workshop. Having identified emergent topics that had potential to leverage overlaps in Faculty Fellows' interests, facilitators broke the Student and Faculty Fellows into two teams to further explore these topics. Visiting PIs led these teams through a series of activities based on the Creative Anticipatory Ethical Reasoning (CAER) protocol developed by York and Conley [31].

The CAER protocol is used here to further cultivate interactional competence within each team while facilitating the collaborative, critical interrogation of plausible futures in relation to the selected topics. It does this by integrating elements of scenario analysis, design fiction, and ethical reasoning: guiding the team through identifying values and aspirations related to their topic, analyzing trends and events that might be impactful, juxtaposing quick draft versions of images and text to elicit further examination of a particular scenario, and then applying an ethical reasoning framework to attend to how different relevant social actors might experience the scenario.

Through a CAER workshop, participants have an opportunity to bring their different knowledges to bear in a way that enables learning about each other's expertise and values in the context of a particular domain topic. In this instance, the two topics were "The Future of Durable Cities" and "Plastics Pollution." These conversations raised collective discussion about the challenges of power dynamics and market-driven economic systems that shape sociotechnical systems.

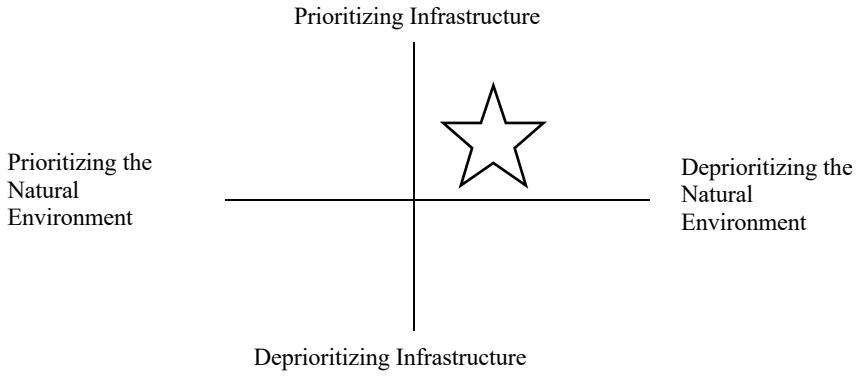


Figure 5: An example of a set of drivers brainstormed to support development of a scenario related to the "the Future of Durable Cities." In this case, a scenario in which infrastructure is prioritized and the natural environment is deprioritized in the development of durable cities has been selected for exploration.

To connect this activity to teaching, two members of the visiting research team had an opportunity to share additional teaching techniques at the end of this session. Visiting faculty PIs demonstrated a teaching technique related to inviting students to consider different affective responses to a sociotechnical problem and led the fellows through a collaborative research and writing project.

Pedagogical Planning and Feedback

Finally, in the third workshop event before Spring semester started, Faculty Fellows and members of the Mines PI team met in an informal, 2-hour meeting. Attending Faculty Fellows shared plans for their course implementation and solicited feedback from local PIs and other Fellows. Faculty Fellows reported developing different kinds of things for their classes, including:

- reflection videos
- personal essays
- a series of scaffolded explorations of key concepts
- and invitations for future collaborations

Research

Throughout these activities, we undertook various research activities. Data collection, formal interviews, informal reflective conversations, and participant observations at events and classes is ongoing. This paper reports on a subset of these materials: two sets of formal interviews. We conducted one set of interviews with Faculty Fellows before they began to engage in the planned workshops described above, and another set of interviews with the Student Fellows after all the activities were completed. For all of these interviews, we used a standard semi-structured

interview protocol developed to elicit reflections on site-specific issues and personal experience related to pedagogy and interdisciplinary experiences. We recorded these interviews and had them transcribed before reviewing and correcting them. Three Student Fellows worked with Mines PIs to conduct thematic analysis on this material as well as transcriptions of interviews and event recordings [32].

With the data we report on here, we explore how conditions of this engineering-focused university frame both faculty and student reflections on interdisciplinarity and pedagogy. More specifically, we can see how engineering-focused educational contexts shape courses as well as student and faculty experiences. Students reflected on the limits of a traditional engineering education and their own agency to advocate for change. We expect that further interviews will illuminate Faculty Fellow reflections related to issues including: the workshop events, the experience of working with students, and teaching at Mines.

Table 2. Interviews conducted and analyzed.

Pre-event interviews: Faculty Fellows	**Post-event interviews: Student Fellows**
4	7

Preliminary Findings

1: Faculty and students describe an engineering-focused educational context that shapes courses as well as student and faculty experiences. Within this context, much of the specifically interdisciplinary pedagogy they discuss involves a one-way diffusion of ideas and techniques from the humanities, arts, and social sciences into classes taught in STEM fields.

The ways that Faculty Fellows described their interest in interdisciplinary connections were framed by aspects of their institutional context that shaped what they had experienced and could expect. The engineering-focused environment fundamentally shapes how all aspects of pedagogical experience at Mines. One Faculty Fellow summed up her perception of this educational space: "*Mines…is a is a place where you come to escape all things humanities.*" She recounted negative experiences with STEM faculty who had made her feel as if her humanities expertise had no place on campus as well as students who could not, at first, find utility in courses she taught.

Several Student Fellows also discussed a lack of strong interdisciplinarity in their educational experience, explaining that many of their traditional STEM majors focused only on STEM topics. In one Student Fellow's words: *"there's not really a strong requirement for interdisciplinary work with … most of my classes from my major."* For most, humanities, arts, and social science or project-based courses are only part of their experiences in the first and final years of their programs. While initially resistant, students may often come to appreciate and even enjoy their required humanities courses (as one humanities faculty interviewee explained), they may not actively seek out additional experiences outside of STEM. Such experiences are available through the honors program, very specific majors, elective courses, or projects like CREATE/STS.

When engineering faculty involved in this project described how they worked interdisciplinary material into the classroom they spoke about what they thought would support student learning,

most raised concerns about time and value. One Faculty Fellow thought that he could make time for additional interdisciplinary elements that had impact for students and the way they might appreciate the topics he taught. "Y*ou know, we all say we don't have time to add new things. I feel like I do have time to add new things. It just has to be worth it."*

The single STEM-trained Faculty Fellow who was already teaching material borrowed from the humanities before the workshop was doing so in an honors program, not in a STEM program. Other Faculty Fellows had less experience with this kind of work. One described how she had developed curiosity through collaboration with colleagues trained in social sciences: " *I have considered things that I have never considered before, such as socio-technical kinds of solutions,"* she explained, "*and I guess those are questions that I think folks with a traditional engineering background don't ever learn to ask."* She went on: "*I want to do more things like that. I don't have real experience with it."* She and other Fellows signed up for the CREATE/STS activities because of this kind of interest.

While Faculty Fellows trained in humanities, arts, and social scientists also described finding CREATE/STS activities potentially useful, none described looking for novel orientations to their course topics from wholly different disciplines than their own. In fact, one described interest in exploring STS (a field that studies STEM-based topics but that draws its approaches primarily from humanities, arts, and social science) and another explicitly spoke about being there to act as a resource for faculty trained in STEM rather than to draw their insights into her course. In other words, if the STEM faculty were there to learn, humanities, arts, and social sciences faculty were there to teach.

2: Students describe how this interdisciplinary project encouraged them to reflect on the limits of a traditional engineering education and their own agency in their courses.

Student Fellows had different kinds of interest in interdisciplinarity than Faculty Fellows did. While they had less disciplinary training than the faculty participants, most of them had several years of experience as students in a traditional engineering-focused educational context. Many had joined the CREATE/STS project because they wanted to engage in work across disciplines as well as research. Their involvement, in turn, gave them opportunities to reflect on engineering and how their education was framed in ways they were not usually able to.

One Student Fellow shared thoughts on the ways her engineering courses were shaped, noting that during the project she found herself,

> *Starting to think about why are my classes structured the way they are? Why was this created in this way? What is this trying to do? And really starting to notice that there isn't a lot of room for [interdisciplinary] integration. …. And it just made me very aware of it in a way that I hadn't been before.*

Student Fellows thought that interdisciplinary work, especially the kind that put engineering concepts into context, might have direct applications in their futures. As one explained, in engineering courses, "*You don't learn how to take a concept and look at the implications of it. You learn how to take a concept, embed it into your memory and apply it to a very specific set of problems."* Concepts from humanities, arts, and social science—such as considerations of value, identity, and power—could help him consider those implications. Student Fellows did more than reflect on their engineering coursework, though. They discussed the changes they would like to see. As one put it, work on this project *"got me… thinking about Mines and education and how*

things are taught here and how well, not only just how is it taught here, but how could it be better?"

Not only did work on the CREATE/STS project encourage Student Fellows to consider their education, but it also allowed them to interact with faculty more than they might have otherwise. One described enjoying conversations with her professor "*about …having fun in her class and incorporating important values, even though it was like a 500-level civil engineering class."* This, in turn, had implications for her sense of community at Mines.: "*Now I know a bunch of professors on campus that I would have never known, but I, I know that they all have similar values, which is super cool."*

Another Student Fellow reflected on what how growing community and ease with faculty could facilitate advocacy in the classroom. She explained that if a student had potentially useful suggestions, "*The teacher might be more inclined to make those changes because it's coming from someone that knows them and knows like their style."*

By participating in these interdisciplinary workshops, students were able to voice their thoughts, suggestions, and concerns in a supportive and non-threatening environment. This facilitated open dialogue and fostered mutual understanding between faculty and students. The collaborative atmosphere encouraged students to share their perspectives on their education, without fear of negative consequences. We do not yet know what Student Fellows will do with these experiences, but they describe the kind of environment that we hoped to cultivate.

Discussion and Conclusion

With the intention of facilitating and studying interdisciplinary engagement, we undertook a series of events and activities involving Faculty and Student Fellows at Mines. Further research will be necessary to consider whether and how these activities support the creation of novel interdisciplinary pedagogy. With this paper we describe the CREATE/STS project. We address the conditions for interdisciplinary at Mines, drawing insights from interviews with Faculty and Student Fellows. We also consider critical student reflections on their engineering education developed in the context of work with this project. We look forward to sharing more information about CREATE/STS activities as they unfold.

References

[1] Seabrook, B. E., & Neeley, K. A., & Zacharias, K., & Caron, B. R., Teaching STS to Engineers: A Comparative Study of Embedded STS Programs ASEE Annual Conference & Exposition, 2020.
[2] Marshall, W., & Tang, M., & Durham, S. A. Integration of Science, Technology, and Society (STS) Courses into the Engineering Curriculum Paper presented at 2012 ASEE Annual Conference & Exposition, 2012.
[3] Tomblin, D., & Mogul, N. "STS Postures: Changing How Undergraduate Engineering Students Move Through the World "Paper presented at ASEE Annual Conference & Exposition, 2022.
[4] ABET, Accreditation Criteria 2023-2024 https://www.abet.org/accreditation/accreditation-criteria/accreditation-policy-and-procedure-manual-appm-2023-2024/
[5] Hoople, Gordon D., and Austin Choi-Fitzpatrick. Drones for good: How to bring sociotechnical thinking into the classroom. Springer, 2022.
[6] Reddy, Elizabeth, and Juan C. Lucena. "Engagement in practice paper: Engineering students vs. geological risk in the gold supply chain: Using geological risk in gold mining communities to overcome technical instrumentalism among engineering students." In ASEE Annual Conference & Exposition. 2019.
[7] National Academies of Sciences, Engineering, and Medicine. *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree.* Washington, DC: The National Academies Press, 2018.
[8] Snow, Charles Percy. "Two cultures." Science 130, no. 3373 (1959): 419-419.
[9] Leavis, Frank Raymond. *The Two Cultures?* Cambridge, Cambridge University Press, 2013.
[10] Burnett, D. G. "A view from the bridge: The two cultures debate, its legacy, and the history of science." *Daedalus*, 128 no. 2 (1999), 193-218.
[11] Franklin, Sarah. "Science as culture, cultures of science." Annual review of anthropology 24, no. 1 (1995): 163-184.
[12] Reddy, Elizabeth A., Stephen Campbell Rea, and Qin Zhu. "Ethics by the Dose: Medical Treatment Metaphor for Ethics in Engineering." ASEE Annual Conference & Exposition*,2020*
[13] Luke, C and Jennifer Gore. Introduction. In Feminisms and Critical Pedagogy, C. Luke and J. Gore, Eds. New York: Routledge, 1992, p. 1.
[14] Galison, P "Trading with the enemy."in *Trading zones and interactional expertise: Creating new kinds of collaboration,* M Gorman, ed. Cambridge, MA: The MIT Press, 2010, 147-175.
[15] Infusing Ethics Selection Committee, *Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs*, Washington, D.C.: National Academies Press, 2016.
[16] Bielefeldt, A. R. "Infusing macroethical ideas into a senior engineering course," ASEE Annual Conference & Exposition, New Orleans, Louisiana, 2016.
[17] Downey, Gary Lee, "What is engineering studies for? Dominant practices and scalable scholarship," *Engineering Studies*1 no. 1 (2009) 55–76 .

[18] Downey, Gary Lee, and Teun Zuiderent-Jerak, eds. *Making and doing: Activating STS Through Knowledge Expression and Travel*. Cambridge, MA: The MIT Press, 2021.
[19] Collins, Harry, Robert Evans, and Mike Gorman. "Trading zones and interactional expertise." *Studies in History and Philosophy of Science Part A* 38 no. 4 (2007): 657-666.
[20] Collins, Harry, and Robert Evans. *Rethinking expertise*. Chicago: University of Chicago Press, 2008, 30-31.
[21] Conley, Shannon N., and Erik Fisher. "Developing a theoretical scaffolding for interactional competence: A conceptual and empirical investigation into competence versus expertise." *The Third Wave in Science and Technology Studies*. Caudill, David and Shannon N. Conley et al. Eds. Palgrave Macmillan, 2019. 236.
[22] Bendix, Regina, Kilian Bizer, and Dorothy Noyes. *Sustaining Interdisciplinary Collaboration: A Guide for the Academy.* Urbana-Champaign: University of Illinois Press, 2017.
[23] Committee on Facilitating Interdisciplinary Research. *Facilitating Interdisciplinary Research*. Washington, DC: National Academies Press, 2004.
[24] Reddy, Elizabeth, Gordon Hoople & Austin Choi-Fitzpatrick "Interdisciplinarity in Practice: Reflections on Drones as a Classroom Boundary Object," *Engineering Studies* 11 no 1 (2019) 51-64.
[25] Strathern, Marilyn. *Commons and Borderlands: Working Papers on Interdisciplinarity, Accountability, and the Flow of Knowledge*. Oxon: Sean Kingston Publishing, 2004.
[26] hooks, bell. *Teaching to Transgress: Education as the Practice of Freedom*. New York: Routledge, 1994.
[27] Freire, Paulo. *Pedagogy of the Oppressed*. New York: Continuum, 2000.
[28] Gore, "What Can We Do For You!" In *Feminisms and Critical Pedagogy*, C. Luke and J. Gore, Eds. New York: Routledge, 1992.
[29] Fisher, Erik, Roop L Mahajan, "Contradictory intent? US federal legislation on integrating societal concerns into nanotechnology research and development," *Science and Public Policy*, 33, no 1 (2006) 5–16.
[30] Fisher, Erik, and Daan Schuurbiers. "Socio-technical integration research: Collaborative inquiry at the midstream of research and development." *Early engagement and new technologies: Opening up the laboratory*. Dordrecht: Springer Netherlands, 2013, 97-110.
[31] York, E., Conley, S.N. "Creative Anticipatory Ethical Reasoning with Scenario Analysis and Design Fiction." *Sci Eng Ethics* 26 (2020), 2985–3016.
[32] Braun, V., & Clarke, V. "Using thematic analysis in psychology." *Qualitative research in psychology*, 3 no 2 (2006), 77-101.