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Media(ting) the Socio-technical Divide: a Course Model for Enabling Socio-technical Thinking Using Performance Pedagogies

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1. Introduction

Integrative engagement with the humanities enriches an engineering education in instrumental ways, by instructing transdisciplinary competencies that improve a student's problem-solving readiness, and in ways that facilitate deeper shifts in mindset, including greater reflexivity, improved awareness of the social context for engineered solutions, capacity to grapple with ethical complexity and the ability to understand and harness multiple epistemologies. But while we can develop educational experiences that facilitate this integration, engaging the community of engineering students that we wish to empower can be a challenge. As Pawley argues, "…boundary work is bigger than simply differentiating one academic discipline or organizational arm from another: the metaphor of a boundary prompts consideration of the ideas of inclusion and exclusion, as well as how various material and immaterial groups are differentiated." [1]

This case study shares an example of this type of boundary crossing in an elective course for engineers, Introduction to Science Communication, at the University of Toronto. The course employs pedagogies from theatre and performance studies to help engineering students develop their communication skills, as well as their ability to understand multiple perspectives and to think critically about complex socially contextualized problems. The elective serves as a model for socio-technical integration: students within this classroom are familiar with the material conditions of their environment—an engineering classroom, a community of fellow engineering students, an instructor who is familiar with the discipline—but are engaging with unfamiliar epistemologies and pedagogies; in this way the course helps students and instructors bridge the socio-technical divide.

Performance functions as a critical paradigm in this course [2]. It provides a lens for critical analysis, as students investigate what is occurring when scientific information—their dominion of expertise—is being communicated to or performed for the public. It is also deployed in situated learning, as students take on and perform different roles in the science communication process. It is one such activity that we describe in this paper, and which provides students with the space to straddle the boundary between science and the arts.

2. Context: Engineering and Humanities Intersections project

Despite lively discourse on the importance of broadening scope in engineering education and specifically the value of integrating humanities into engineering to accomplish this goal, many questions remain about how to do this in practice, especially given the range of different institutional and educational contexts at play [3] [4] [5] [6] [7]. Vestigial arguments that pit engineering students and engineers against their humanities counterparts further frustrate moves towards an integrated curriculum; these arguments underscore the need to provide credible evidence that an integrated humanities and engineering curriculum is not only valuable but achievable. Just as the discourse around the liberal arts is inexact, the metrics by which we measure the success of liberal arts and humanities integration is nebulous. Arguably, more demonstrable examples of how particular humanities opportunities lead to particular outcomes is exactly what is needed to make evidence-based arguments about the importance of this teaching.

The Engineering and Humanities Intersections study responds to this gap by observing student experiences as they learn across disciplines to better understand how these learning experiences work to support the outcomes that are associated with a liberal arts education, namely enabling transdisciplinary competencies—communication, teamwork, project management, professionalism—and broadening mindsets—an ability to understand alternate epistemologies and others' perspectives, an appreciation of the social and environmental context of engineering work, self-awareness and ethical reasoning, and a capacity for critical reflection.

A suite of engineering electives at the University of Toronto provided a unique context for this project. These courses were introduced in 2008 to provide interested undergraduate engineering students with an opportunity to engage with the humanities while acknowledging the constraints of their timetable and workload and the challenge of competing for course enrolment across faculties. The courses drew on the expertise (outside of engineering) of faculty working within the Engineering Communication Program, who took the lead in course development and instruction. In shaping these courses instructors could draw on their disciplinary backgrounds to develop curricula that simultaneously introduces students to a new discipline, connects this disciplinary content to issues and topics in science that are relevant to this student cohort, and utilizes both familiar and unfamiliar pedagogical approaches. The elective classrooms are cognitively close to engineering, physically situated within an engineering building and coordinated by instructors who straddle the worlds of humanities and engineering. Students within the classroom are engaging in multiple interdisciplinary transactions, with the course material, which may be highly unfamiliar, and with their classmates, who come from various engineering fields (students at the University of Toronto major in one of nine engineering specializations), each of which provides a different level of engagement with transdisciplinary competencies.

Data collection for Engineering and Humanities Intersections occurred in two of these electives: Representing Science on Stage and Introduction to Science Communication, as well as a student-run musical revue, Skule Nite. Although initial data collection occurred during the 2015/2016 academic year, much of the analysis was completed in 2022. The fragmented nature of this study (an unforeseen result of personal and professional factors) lent itself to an autoethnographic approach to data analysis and reporting, which made use of the primary investigator's perspective as an instructor and researcher navigating, like her students, a space between traditional disciplinary boundaries. It also acknowledged the PI's dual roles as researcher/observer and instructor/designer. The Engineering and Humanities Intersections project comprised the dissertation work of the PI, but before starting the project and after completing data acquisition, she was co-instructor for Representing Science on Stage, and since 2023 she has taught Introduction to Science Communication.

This co-authored paper focuses on one of the three study sites, the Introduction to Science Communication classroom, and from this point forward stays true to the autoethographic style of the study: the study methodology and observations are told from the (first person) perspective of the PI. At the same time, it acknowledges the contributions of the original course instructor (CI) in the course design and his input in helping to understand classroom practices within the context of performance studies [8] [9]. As the course evolved, this research project and our shared discussions around the pedagogy both informed and helped to shape the course and accompanying research.

This paper shares findings from the Engineering and Humanities Intersections project, while simultaneously discussing the efficacy of specific pedagogical strategies used within the Introduction to Science Communication classroom. We will begin with an introduction to performance pedagogies, a concept which informed classroom practices and analyses, introduce the methodology of the overall study to provide context for the observations provided here, describe a specific pedagogical approach that is emblematic of the course pedagogy, and conclude with insights from student interviews and classroom observations about the outcomes of these types of instructional approaches. Rather than providing a separate literature review section, relevant theory is introduced throughout the paper, recognizing that sections of this paper are excerpted or adapted from a larger project that is anchored in literature on interdisciplinary and transdisciplinary studies, liberal engineering and pedagogical practices.

3. Performance as a critical paradigm

In *STEM, Theatre Arts, and Interdisciplinary Integrative Learning*, theatre professor and interdisciplinary advocate Nancy Kindelan makes an extended argument for the value of theatre integration in STEM. Her book both acknowledges growing support for the value of integrative disciplinary opportunities, and calls attention to the disciplinary boundaries that hamper new interdisciplinary initiatives. Kindelan highlights theatre as an ideal vehicle for interdisciplinary learning, arguing:

> Courses in theatre are intellectually, psychologically, and emotionally enriching; they encourage students to consider their place in society—past, present, and future; they teach critical thinking, analytical, and communication skills that help students identify, analyze, and speak to complicated technical, economic, political, and social problems; they engage students in collaborative, experiential problem solving. [10, p. 106]

Her argument aligns with scholarship on the value of performance as a critical paradigm, a term coined by theatre scholars Freeman and Gallagher to describe the way that performance can be deployed as a useful critical paradigm across different disciplines [2]. Performance provides valuable methods and models for teaching and learning across disciplinary boundaries; presenting enabling pedagogical strategies to broaden engineering mindsets and support the development of transdisciplinary competencies. This study also considers how these humanities sites successfully employ performance paradigms, and how these particular techniques can help students to develop perspectives, skills and behaviours that may complement a "conventional" engineering curriculum. As such, the Engineering and Humanities Intersections project, considers the following questions:

1. How might interdisciplinary pedagogical approaches to engineering curricula such as those from theatre and performance studies disrupt or challenge engineering epistemologies and student mindsets?

2. What can such disruptive pedagogical approaches reveal about the relationship between classroom environment—both physical and in terms of community—and student learning?
3. How do students themselves understand the impact of those approaches, especially as it pertains to their futures in engineering?

This paper focuses on the first of the three questions, though the second and third are also explored through the resulting analysis.

4. Methodology

I utilized a constructivist grounded theory approach to this project, spending time observing and sometimes participating in the classroom or rehearsal environment and using fieldnotes to identify ideas and emerging theories [11]. These observations were enriched by student insights gleaned through interviews with thirteen participants across the three sites, as well as written assignments, performances and presentations in the courses, and a final performance and rehearsal materials in the student-run extracurricular. A breakdown of the data sources from each site is provided in Table 1 below.

Table 1. Data Sources

	On-site observation	Participant interviews[1]	Submitted assignments	Presentations	Course Materials
Science on Stage	✓	6	✓	✓	✓
Skule Nite	✓	5			
Introduction to Science Communication	✓	4	✓	✓	✓

Four students from the Introduction to Science Communication course, the focus of this study, volunteered to participate in interviews and share assignments from the course, though all registered students were aware of and consented to classroom observation under the ethics protocol approved by the University of Toronto Research Ethics Board in 2015. The participating students, described using pseudonyms here, were Olive and Amara, both fourth year Chemical Engineering students, Moe, a fourth year Electrical and Computer Engineering student, and Seema, a fourth year Civil Engineering student.

The semi-structured interview protocol, which was consistent between all the study sites, is included here as Appendix 1.

[1] Some interviewees participated across sites, so although I conducted fifteen interviews this accounts for only thirteen participants.

5. Performance pedagogy in the Introduction to Science Communication classroom

Introduction to Science Communication is a Humanities and Social Sciences elective offered through the Faculty of Engineering and available to students from across all engineering disciplines in years two to four of their program. The course is relatively small, with typically around twenty-five students registered, which helps to facilitate the seminar style discussion and many group activities that comprise the instructional approach of the course.

In the course students conduct close readings and analysis of a variety of popular media types that are typically explored in relation to a single story. For example, in a multiclass sequence students analyze how climate change is discussed by different news outlets, framed by multiple documentarians and politicized by different parties; in another exercise they trace the history of misinformation tied to a particular innovation, the Gardasil vaccine, and apply lessons from that coverage to contemporary vaccine skepticism; they look at coverage of the super hadron collider from its press conference at CERN, in CERN's educational resources and in a popular podcast. This comparative approach to media analysis emphasizes the power of storytelling in popular science communication. Comparison is also encouraged between the same genres and tools deployed in service of different stories. In this way students are encouraged to consider how messages are constructed and conveyed through and across related texts and different media, and to critically assess these messages. Performance is used within this course both as a pedagogical tool to frame the production of communicative objects in situated learning, and as a critical paradigm to analyze science communication in the media. Instructors of engineering communication will be familiar with the value of situated learning in helping students to develop knowledge and skills that can be applied to future professional contexts. Here, I discuss situated learning as an example of performance pedagogy, as students are encouraged to try-on different roles and perspectives in these activities.

Scholars in the field of Performance Studies have for decades been adapting theories from Theatre Studies to think about how performance plays a wider role in society. Performance Studies scholar Laura Levin advocates for the value of performance studies as a critical tool, arguing that this "field [which is] attuned to the enactment of self in the spaces of everyday life, exposes the ubiquity of theatrical paradigms in our digital age" [12, p. 168]. Levin problematizes the 'ampersand of performance' – a perfunctory tacking on of performance to departments including theatre and communication, arguing instead that performance is an increasingly valuable critical paradigm by which to analyze subjects across disciplines. Levin borrows from Judith Butler's distinction between theatre and performance to acknowledge the bleeding of performance into every interaction and in turn every discipline [13], explaining: "theatre often suggests a self-conscious act in a delimited space; it is framed by a set of artistic conventions that, in some way, acknowledge its artifice. Meanwhile, performance enjoys no such distance from 'the real.' It describes instead those quotidian acts by which the illusion of identity is repeatedly, mostly unconsciously, naturalized." [12, p. 170]. Whereas theatre studies is often constrained to a Theatre Studies department, focusing on the performance or analysis of theatrical texts, performance studies can be used across disciplines and disciplinary spaces as a tool to understand how performance permeates all social interactions. Performance as a "mobile critical paradigm" then can be deployed in different contexts to acknowledge and explore the ways that identities and messages are self-consciously constructed and performed [2].

5.1 Creating a science story using roleplay

A science story writing exercise provides a useful example of how performance approaches can be used in the engineering classroom to support the development of transdisciplinary competencies and mindsets. In this exercise students are asked to roleplay the position of science journalist to communicate the significance of findings as shared/received by a scientific "expert." In order to emphasize how messages are crafted by various outlets/actors, students are first asked to deconstruct a science article based on the work of a University of Toronto lab by answering the following questions: 1) How do you think the author arrived at the title and lede?; 2) How accurate/accessible is the newspaper article?; 3) Who is in control in this writing process?; and 4) Who has agency over how this story is told/these facts are shared? [14] This discussion emphasizes the role of the journalist in mediating and crafting messages, and encourages students to consider how different subjects or positions impact the way that a message is shaped before they have a chance to adopt the role of communicator.

Next, students are introduced to another area of research, Electromicrobiology, at the University of Aarhus. They are provided with two articles on the discovery of chain-bacteria by the Nielsen lab in Aarhus. These chain bacteria apparently communicate from the seabed to the ocean's surface, and this phenomenon is described in an article in *Nature* authored by Lars Nielsen and his team, as well as the University of Aarhus's original presser [15] [16]. Students are asked to use these materials to generate their own popular media article in a small group, and they are told that the winning article will be selected by popular vote in the next class. In writing their article they are encouraged to work through another set of prompts: 1) What title and lede comes to mind based on what you're reading?; 2) How will you use this press release?; 3) Which details are important? What will you include/exclude?; 4) What additional sources of information would be helpful?; 5) What kinds of questions would you ask the authors of this press release if you could? [14] After allowing the class to initially grapple with these prompts in small groups, the CI introduces a fictional guest from this lab, a post-doc named Brita Inge Lehmen. Each group is allotted 10 mins to interview Brita using questions they generated. Conveniently present as classroom observer throughout this activity, I first played the role of Brita in 2016 and continued to join the class as a guest in subsequent years. The role was passed along to the former CI when I took over instruction of the course in 2024.

This roleplaying pedagogy, in which a guest observer occupies the role of a visiting scholar as students try-on the role of science journalists, recalls Heathcote's Mantel of the Expert approach, in which an instructor can guide students through investigation by adopting the role of an expert from outside the conventional classroom space [17]. Similarly, this activity evolved from our own teaching backgrounds. Roleplay is an established pedagogical tool in engineering, often deployed in problem-based or situated learning scenarios to help students better understand professional engineering environments. In these cases the instructor may adopt the role of manager [18] or client [19] [20], situating the student as stakeholder [21], designer [22], or consultant [23]. Roleplay can also be deployed as a strategy for teaching teamwork, leadership and ethics in engineering [24] [25] [26] [27].

This activity asked students to adopt the role of science journalist through the process of researching and writing an article based on a science press release. Although the activity was ostensibly an exercise in written communication, it also required students to effectively prepare for and interview a scientific "expert". The classroom space was transformed into a busy newsroom—the context slides for the lesson included a still from the movie *Spotlight*, in which the reporters huddle together in intense conversation. Student work was punctuated by the editor's (CI's) vocal interjections as he counted down the clock to print deadline. His participation in the exercise increased the intensity of the work period but also contributed to the playfulness of the scene. Engineering students embraced the opportunity to play.

Within the context of this conceit students could try-on the professional personae of science journalist while using the interview to gather more information. For all of us, the playfulness of the exercise and the sometimes silliness of our assigned characters—the classroom observer enlisted as a Danish grad student specializing in chain-bacteria—made space to self-consciously define these constructed roles. The value of the roleplay as a mechanism to better understand the norms and characteristics of a science journalist is evident in one of many lighthearted exchanges:

> **Student 1**: Ok. What are the possible applications of this sort of thing?
> **Brita:** Right now? Who knows. I think there are so many applications. You look around at the world around us and how reliant we are on different types of—
> **Student 1**: This sounds like we're heading towards our title—
> **Student 2:** Hey, you can't corrupt our witness—
> **Student 1:** It's not a court of law. We're journalists.
> **Brita:** I can give you what we say in our article, which may sound kind of boring, but it's that energy production, waste treatment and biosynthesis are all potential applications.
> **Student 1**: I was looking for something out of the box. This is conventional stuff. [28]

Both students here work to define the task and role of science journalist. On the one hand, Student 1 doggedly pursues a title, looking to land quickly on the outcome of this interview activity: a pithy hook. Student 2 on the other hand, assumes the role of journalist as interpreter: they must listen to facts and reframe this story for an unfamiliar audience. In adopting this role, however, they also try on another professional personae by evoking legal language to keep their interview partner in check.

Reading over this exchange and others I was struck by my ability as Brita to speak a great deal without really saying anything. Arguably, my contributions in this exercise point to the potential of a decontextualized soundbite to hold meaning that supersedes its original use. The following exchange, which I have annotated with stage directions to capture tone, exemplifies the murkiness of my answers and the generosity of the students who continued to engage through the silliness:

> **Student 3:** So, is this bacteria easy to collect so to speak, or do you guys have one sample and that's it?
> **Brita:** Oh no, it's easy to collect.
> **Student 3:** It's all over the sea floor?
> **Brita:** At least the lake. Our starting point was the lake that our university is named after, called Lake…*(beat)*
> **Student 3:** Lake Aarhus?

Brita: *(Joking.)* Right, it's like you know our geography better than I do. This is where we first observed this occurring, and now we've replicated that in our lab. So, in that way it was easy to come by that bacteria.
Student 3: And how did you prove? How would you describe the proof that this was an electrical current, as opposed to something like—whether it was an electrical process or a diffusion of molecules?
Brita: *(Buying time.)* So, how did we prove it?
Student 3: What technology or things did you do? Or did you just sort of infer that it couldn't possibly be the diffusion of molecules, it had to be electrical.
Brita: *(Hesitating.)* Hmmmm. We—just let me consult my notes for just a second—let me take a look. *(Beat.)*
Student 3: *(Patiently.)* Go ahead.
Brita shuffles notes…
Brita: These mass-balance calculations were one thing that we did. *(Points to article.)* That's really all that we talked about in the article.
Student 3: *(Sarcastically.)* Calculations?
Brita: *(Confidently.)* Yep, calculations.
Student 3: *(Dismissively)* Calculations, cool.
Student 4: What was the cost of this research and how long did it take you?
Brita: *(With more confidence.)* That's a good question. We've been involved in this research for about—well, Lars my supervisor, took it on before me. I'm a fairly junior researcher, which may be evident from this interview.
Student 4: *(Lightheartedly.)* You cannot tell. You really cannot tell.
Brita: So, he's been working in this area for six years and I just came to the lab last year. It's been a six-year project. It hasn't been—*(evasively)* I couldn't tell you exactly how much it's cost—because of course that's Lars's department—at the University of Aarhus he's one of the most well-funded researchers for sure. He's gotten a lot of grants together to do this research.
Student 4: Do you have maybe a ballpark number that was thrown around maybe? Is it in the tens of thousands or the millions?
Brita: *(Very confidently.)* Oh, it's in the millions. This is a very good lab. And it's an exciting time to be here, right, and see how those millions are being spent.
Laughter from all. [28]

This activity is designed to emphasize the mediating role of science journalist in interpreting and reframing innovation for a lay audience, but it also exposes the importance of effective communication and valid expertise on the part of the scientist as communicator. In 'real life' Brita's familiarity with the Nielsen Lab would give her insight into the science discussed, but her perspective and interests, the focus of her interview, might differ from the primary talking points of other members of the lab, and would be guided by the questions that each team chose to ask. More importantly, within the conceit of the fictional interview, Brita is an inherently weak spokesperson for the Nielsen lab. Although I invested time preparing to play this part by reading backgrounders on the lab and reviewing popular science articles (students were only introduced to these in the debrief stage of this activity), the idea that I am an expert in this technology is absurd, and my responses to student questions belied my ignorance.

Despite the obvious limits of knowledge, many students continued to question me about technical elements of the science in great detail, seemingly sticking to the belief that I had access to insider knowledge unavailable to the larger group. For example, a key characteristic of the chain-bacteria described in the article is their ability to communicate across distances up to 20,000 times their size; each of the teams probed me for a corresponding distance or a clear implication for this distance, asking: "Is that like [20,000] a somewhat upper limit then?"; "And for the bacteria, they mention that it's 20,000 times the distance. Like how far apart they can be? Can it be farther apart or is that typically the average distance they were?"; "We have one last question: the article says, or the press release says that they can produce currents more than 20,000 times their own length. How big is this actually? How significant is this length actually?" [28]

The student articles produced from this activity speak to their focus on the power of an effective title and lede to capture audience attention. In fact, their framing strategies, "Bacterrys: Spark Green Energy Alternatives—Aquatic Bacterial Nanowires May Unlock a 'Myriad' of Potential Applications to Green Energy, according to Danish researchers"; "Scientists Discover Bacteria Grow Their Own Power Grid"; "Bacteria Use Their Own Sharing Economy"; "Bacteria Have Their Own Wi-Fi Network", closely resemble those deployed by professional journalists who originally covered the story, which included "Bacteria buzzing in the seabed—Nanowires growing from bacteria might link up distant chemical reactions in sediments" [29]; "Deep-Sea Bacteria Form Avatar-Style Electrochemical Networks" [30]; and "Pandora Bacteria Act as One Organism" [31]. But beyond this practical lesson in science communication, students also appeared to be excited to try on a new professional role.

Through this exercise students engage in the type of situated learning that is central to communication instruction in engineering. This activity, however, pushes beyond more conventional situated learning scenarios by asking students to engage in improvised roleplay in an unfamiliar role. When students are asked to take on the role of a science journalist working against a deadline, they are adopting a new and novel authorial voice within a context that is distinct from typical professional contexts in engineering. They are also approaching the act of communication with greater urgency than they may be accustomed to in their engineering classrooms; the deadline clock after all is ticking. The frantic timing of this exercise may contribute to the ease with which students adopt their new role. Within this classroom turned newsroom, they lack the time to question the fictional conceit of the activity without redirecting energy from their goal of producing a complete news article. Students also lack the time for reflection that might lead to greater self-awareness. Although making time for reflection is an important benefit of the course as a whole—frequent analysis and discussion, which encouraged students to position themselves in relation to course material was a key feature of the course—here, giving students more time to think might interrupt student engagement with the activity and contribute to their self-consciousness. These time constraints, also, arguably, contribute to the fun of this activity: in the improvised roleplay I am challenged to generate off the cuff reactions to student's questions, and students are encouraged to volley back with questions and comments of their own.

William Frey proposes roleplay as an important teaching tool to promote a 'moral imagination' in future engineers; he frames this approach as a method to not only practice future scenarios, but also to enable an understanding of multiple perspectives, explaining:

> In order to adapt to *minds differently situated*, engineers role-take with others by projecting into their shoes and collecting their feel of a situation. Through dramatic rehearsals, engineers can test the implementation of decisions and designs in rich and emotionally textured worlds that are constructs of imagination; this helps develop and refine "that delicate knowledge of the heart." Moral imagination supports, builds upon, and even extends engineering expertise and experience to provide a response to global challenges that is socio-technically sensitive, interdisciplinary, emotionally responsive, and successful at integrating technical and moral expertise. [32, p. 236]

Frey's thoughts here echo arguments about the power of performance to provide a space to try-on ways of being and to practice ethical behaviours and outcomes [10] [33] [34] [35]. The fictional newsroom in Introduction to Science Communication invites students to enter a space that is removed from conventional engineering settings, allowing for the type of ethical practice broadly associated with role playing activities outside engineering. While these exchanges with Brita do not require a moral reckoning so to speak, they nevertheless call for students (and instructors) to project themselves into another's shoes. In this case, the students' multidimensional awareness, of themselves as future engineers, current students and imagined reporters provides a mechanism to understand the different ways that information is constructed and valued by different players, as well as the multiple uses of a given technology. In formulating their article, the students are challenged to understand the perspective of their target audience and to construct their pitch to appeal to this group; the varied perspectives necessitated by the roleplay engender this perspective taking. What's more, the practice may better prepare students for this type of subjective shift in future classrooms and professional contexts.

6. Discussion

In the discussion below I integrate student interview responses with my observations on this activity and others in the class, noting that the activity shared here is emblematic of the course's overall pedagogical approach. As noted above, student interviews were conducted with four Introduction to Science Communication students. Because the study originally focused on skill development (including but not isolated to the roleplaying exercise discussed here). I initially reviewed the transcripts to identify complementary skills developed in the course, namely, communication, media literacy, lifelong learning and teamwork, and then coded these transcripts by identifying verbs and phrases associated with the development or application of these skills (e.g. communication—communication, writing, presentations; media skills—analyzing, researching, comparing, assessing; lifelong learning—continuing, applying, learning; and teamwork—group, team, collaboration). This initial analysis indicated that students most frequently mentioned communication as an outcome of this course, and frequently discussed media awareness as a specific skillset of communication. Lifelong learning was discussed in terms of transferability or utility of course concepts. Teamwork was not seen as a central outcome of this course, but students discussed collaborative idea generation while reflecting on opportunities to share ideas in the course.

The interview transcripts were analyzed again following a review of in-class activities to better understand how students discussed the key outcomes observed there: how the class environment helped foster sharing, how students were made more aware of elements of performance in communication, and how course activities seeded creativity.

6.1 Communication

Not surprisingly given the focus of this course, all of the participants indicated that they felt they had significantly improved their communication skills over the semester. This improvement was credited to both the course content and pedagogy. Olive noticed the course's emphasis on complementary or transdisciplinary skills, explaining that "it feels like a liberal arts kind of skill I learned, not an engineering one. I would say that the skills I properly learned are writing skills and presentation skills" [36]. Seema locates the genesis of her improved communication ability in the value of "really good feedback," which "improved [her] presentation skills and [her] writing skills… because it [specified] what to improve on next time" [37]. Amara indicated that she was better equipped to apply to jobs that privileged communication alongside engineering experience. She saw the ability to call on skills from the course as a significant advantage as a chemical engineer graduating into a slowing energy market, explaining: "In Chemical Engineering, because of the oil and gas [slowdown] there just aren't [many jobs]. So, I've definitely been looking at other, I guess marketing and sales [opportunities]. And the skills that we learnt in this [class] can definitely be used there. Again, they all look for communication skills, interpersonal skills…" [38]. Amara's observation suggests not only that she sees herself as a stronger communicator, but also that she sees the potential to transfer these skills to new professional contexts.

6.2 Media literacy/analytical skills

Media literacy was a key learning outcome of the course, enabled by both the close analysis of communication artifacts and students' subsequent production and analysis of their own. While each of the students commented on their improved media literacy during our interviews, some also reflected on how this was helping to improve their work in other contexts. Seema found her improved ability to read and analyze sources valuable to her performance in capstone design, explaining:

> For my capstone I had to read so many reports done by lots of different NGO's … and I think that the course really helped me put it in perspective in terms of like: Why is the NGO writing this? What's their intention behind it? Did they have funding? All that kind of stuff. The governments, why would they be writing? What would be their goal behind writing the reports or their project? … So, there's like maybe three different reports about the same thing, and they're saying different things. And I wasn't just looking at what it said, I was looking at where the report came from and what year was it written and who wrote it, that kind of stuff. [37]

Olive also saw this increased awareness as influencing how she would engage with politics or politically motivated communication in future, explaining that:

> You can look at something and say: 'This is not a very good publication because this is not accurate, they're pulling in sources from here, that's not very good evidence, or [it's

> missing] statistical or anecdotal evidence; it's not very good for you to make a claim.' So, you can kind of assess things, and say whether it was effective in communicating science, whether it was accessible. Now I actually think about the source of funding for some of these things, and why people are saying that, why they're using science in politics—I can now understand that more. [36]

6.3 Lifelong learning and transfer

This media literacy was closely tied up in all the interviews with a desire to continue to engage in science through multiple media and in response to emerging issues. In all the interviews students emphasized a desire to continue to follow outlets introduced within the course. Seema noted that she'd been "introduced to a bunch of podcasts" that she would continue to listen to, and that she was reminded of the *New York Times* science section. She also had "a bunch of books that [she was] introduced to" [39]. Moe described that he found himself reading more, and more widely, and bringing new topics of discussion to his workplace. He explained that: "I guess I was more afraid before that people would just dismiss me, and kind of call me out or mock me. But now I feel a little more comfortable and I would totally be willing to engage in [new ideas]…And when I have the opportunity in the lunchroom [having recently joined an engineering workplace], I'll bring up a topic of discussion, usually try to get something going there" [40].

When asked explicitly about lifelong learning students consistently emphasized the utility of the media literacy skills developed through activities like the story writing activity, and described a drive to remain "on top of the news" in order to be more informed about issues in the media in future. Seema noted that the course had made her "more aware of the scientific community in the media in general," and that this awareness kept her abreast of "which direction engineering and technology and new discoveries are taking." When prompted to consider why this awareness is important she framed it in terms of professional pathways, explaining:

> I guess what I mean is that it's important to understand what direction new technology is going in so you know where to centre yourself…If you were working on something and you know that it is related to something in [a particular] discipline, and then you just know out of general knowledge that in that discipline this is going to happen in the next 15-20 years, then you know that that will impact what you're doing. [39]

Significantly, Seema, like the other participants here, was exiting fourth year into professional industry, and her response belies a particular interest in career paths, but her observation also has implications for engineering work more broadly. Her response acknowledges the importance of understanding the broader social and technological context for one's work, and the implications of new technologies that one may contribute to.

6.4 Teamwork

In general, students did not perceive that this course contributed to their development of teamwork skills, despite the significant time spent in group discussion and activities. Most students described the small group discussions as valuable opportunities to share ideas with their peers but viewed this type of activity as distinct from typical definitions of teamwork. Student perception of these in-class collaborative activities as *not* teamwork may be due to the fact that the teams were not formed to produce large-scale graded projects, as would typically be the case in the engineering curriculum. These team activities were often project and goal-oriented; students did, for example, complete and submit the article on chain bacteria discussed here. However, these teams were temporary and often engaged in an exploratory low-stakes activity: students may not have perceived these as offering the same opportunity to develop team skills as long-term complex team exercises.

Some students framed the collaborative work environments of Introduction to Science Communication as similar but separate from teamwork elsewhere. Amara reflected that she wished she could transfer the environment created within this classroom to "engineering courses" where peer-to-peer connections, which support effective teamwork are not necessarily fostered. She explained that "in engineering you're all serious and [these discussions] would seem a bit off. So that's why [we] would be like, 'why should we be doing this?' We should be concentrating on this, this and this [instead]" [38]. Amara's observations here echo impressions expressed elsewhere in this project: within the high-pressure environment of an engineering classroom students are less likely to justify investing time in the unfocused conversations and group dialogue that can lead to productive idea generation. In an alternative classroom space, where the stakes appear lower, students can practice exploring and articulating new ideas and approaches.

6.5 Confidence

Students pointed to the function of the classroom environment and pedagogical approach in enabling their participation, and suggested that this contributed to their confidence overall. Moe thought that "this course helped [him] open up a lot more," explaining, "before I was kind of a lot more shy than I am now with regards to just explaining—like raising my hand and saying what I have to say rather than waiting on anyone else" [40]. He attributes much of his improved confidence to characteristics of the classroom environment, including the small class size and the rapport of the instructor and fellow students, evidenced in the activity transcripts above. In addition, he acknowledges his own confidence in the material as important to increasing engagement. With some self-consciousness, Moe explained that he was also bolstered because "for the most part…I kind of knew what I was talking about, I guess, a little bit" [40]. Moe explained that he was comfortable engaging with relatively new subjects in this classroom by applying his limited knowledge acquired outside of the classroom via "a few videos" or "a few newspaper articles." He explained that in an engineering classroom: "I'm going to try to figure out exactly what [a concept] means before I can kind of continue and keep progressing" [40]. In an engineering classroom Moe needs to be sure of his confidence in the basics of a concept before he can proceed, but within this other space he appears more comfortable stumbling through content with only a minimal foundation, and as a result potentially making mistakes.

Amara similarly sees the shared background of the engineers in the course and the small class size as important factors in encouraging expression. Reflecting on her experiences in both Representing Science on Stage and Introduction to Science Communication she explained:

> I think what was interesting is that even though it was just all engineers, we all had this, I guess, interest and passion for the courses we were taking. I think it was good in the way that we were able to use our engineering background and bring it to these courses … just working with engineers, with other engineering student I thought it was good that we could learn from people's different experiences … And I think one thing that was great is that the class size was so small for both the courses … I think that's pretty important in the way that you can express your ideas in the way you wanted. And yeah, it just helped with the whole environment: you knew everybody in the class, and you were able to get a gauge of what the different ideas [are] that people are presenting, and I think that was pretty important. [38]

Students see the classroom environment as fostering supportive dialogue and sharing. Amara's observation on the shared disciplinary background of the students in this class is important: she seems to be assuming (like Moe) that ideas would be less positively received in a typical arts and science classroom, but also perhaps in an engineering classroom, which would again be disciplinarily homogenous. Amara emphasizes the size of the class as a key factor in community building, which in turn, fosters a safe space for sharing, but there are other factors at play here too. The perceived identity of all of the members of this community as equally positioned learners (new to this discipline) helps to foster more vulnerable sharing. Exercises that encourage students to view their experience as a valid source of evidence and to take on the mantle of expert also help to encourage students to share. Finally, the course content emphasizes a range of perspectives and a variety of pathways to meet common goals. In reviewing multiple sources on a single topic (an exercise that students complete multiple times as they study different issues in the media), or by making choices about the angle or focus of their own stories, students are made aware of the multiplicity of interpretations of any one event, which challenges notions of a single 'right' answer that might typically direct engineering student work. This content works to free students to express opinions that may be partially formed or tied up with their own experience, a source of evidence that within the 'objective' epistemologies of science and engineering is usually viewed as inherently flawed.

6.6 Performance techniques

Interestingly, despite the repeated use of performance techniques within class exercises and the use of performance as a critical paradigm for analysis, students did not discuss performance within their interviews. This exclusion may be due to the lack of explicit questions about performance, which took on a greater role as I analyzed my classroom observations after conducting the interviews. It may also speak to the fact that performance is a technique used in the course rather than an outcome of the course activities. Students focused on their improved ability to critically assess and consume media rather than to produce it.

6.7 Creativity

Only Moe and Amara commented on the opportunities for creativity within their interviews. Moe noted that he valued the opportunity to "do some creative stuff," and in fact noted that this type of creative output was something that he valued in multiple humanities electives for engineers that he had completed [40]. Amara discussed her "creative thinking skills" in the context of media literacy in the course, seeming to conflate creativity with what we might typically define as analytical skills [38]. Amara’s logic here is interesting. Analytical skills are taught throughout the engineering curriculum as students work to understand and solve problems. They certainly underpin creative acts in this way, especially in as much as engineering design is itself a creative act: our students are creating a designed solution to an engineering problem. The fact that she identifies a crosscutting critical skill as creative in this particular context may speak to how an alternate classroom space, that is positioned closer to the arts, invites students to reinterpret or reframe activities that they similarly use within their engineering work. Indeed, Moe’s appreciation of this opportunity to “do some creative stuff” seems to imply a relative lack of creativity in his engineering design work.

7. Conclusion

We began this paper by acknowledging the complexity of boundary work: the challenge of inclusion and exclusion that inevitably results as soon as we erect or fortify a boundary. Introduction to Science Communication provides an example of effective boundary crossing in engineering, by encouraging students to engage with pedagogies and epistemologies from outside their home faculty. But this boundary crossing is aided by the enthusiasm of its audience: our students are inundated by portrayals of science in the media and many gladly take this elective because it promises to unpack some of what they are consuming. Students see this course as a professional asset. Indeed, its utility as a course that imparts a demonstrable set of serious skills—the ability to analyze an article, to evaluate a source, to communicate about your science in and through the media—makes this course attractive. In all the interviews, students described the utility of their learning here, to their future employability, as well as their own position as a consumer of media.

These observations from students align with insights from Engineering Education literature about the efficacy of humanities opportunities in helping to instruct communication and critical thinking skills. The method of data acquisition via the student interviews also corresponds with the post facto arguments that this literature sometimes forwards: students were commenting on the importance of a given transdisciplinary skill after its acquisition—their focus was on the outcome not the process. Observations of classroom activities and student assignments provide greater insight into *how* students were acquiring these skills, and also demonstrates the importance of pedagogy and classroom environment in helping students to develop and articulate their own subjectivity, to practice engaging with perspectives beyond their own, and to gain greater awareness of the conventions and constructs that infuse media and in turn mediate cultural and professional norms.

In Introduction to Science Communication students are provided with a classroom space where they can analyze and create science communication through a range of pedagogical approaches—just one of which we have shared here. Although the class is not a venue for theatre or performance, instruction utilizes performance pedagogies, notably roleplay and critical paradigms of performance, to better understand how science communication is in itself a type of performance. Yet students appeared to give these strategies minimal thought. Instead, student commentary focused primarily on the role of a supportive classroom environment in fostering their ability to form and articulate ideas and perspectives, and to share these with their peers while experiencing minimal discomfort. They also noted the value of hearing and learning about different perspectives in affirming the value of their own. As discussed above, performance pedagogies employed within the classroom may contribute to this atmosphere; roleplay creates a space for play, and trying on various roles—in this case as journalist, but in other activities as consultant or editorial assistant—helps students practice particular types of communication, while also articulating new ideas within alternative guises. Roleplay, however, is one of multiple teaching strategies that encourage students to express themselves, and arguably there are many factors that helped to create this supportive environment.

This course, like other successful humanities opportunities for engineers, gave students *time* to explore. Within class, this time made space for lengthy conversations in which students could pursue new ideas and investigate their own perspectives as they learnt about others'. The class also allotted time to play, allowing students not only to experience the perspective shift of seeing through someone else's eyes, but also the silliness of trying something new, and the incumbent vulnerability that can make performance such a valuable group unifier [41].

Given the obvious orientation of this content and the course's pedagogy towards conventional notions of science as theory driven and concrete, I was surprised to find lessons in Introduction to Science Communication infused with opportunities to play. But perhaps the proximate location—epistemologically—to engineering helped to encourage this play. Our students, while future engineers and scientists, are also thinkers and learners who value an opportunity to learn through exploration. Here, students were given the space and time to explore new pedagogical and epistemological approaches within a relatively familiar environment and a classroom structure that they recognized. This exploration of new concepts and new ways of learning also consistently led to a concrete outcome, for example an article on chain-bacteria. In this way, the course seemed to strike (for students) a meaningful balance between application and exploration. Cosgrove and O'Reilly argue for a similar balance within core engineering curricula—teaching the foundational theory but encouraging students to reflect upon the application of this theory to practice [42]. Students in Introduction to Science Communication closely explore how abstract theoretical concepts (science) are relayed through tangible sensible systems (media), and in turn become more sensitive to the mechanisms with which these systems are constructed and maintained. This insight enables a critical understanding of subjectivity and perspectivity that challenges notions of engineering epistemologies as convergent and constraining.

Works Cited

[1] A. Pawley, "Engineering Faculty Drawing the Line: a Taxonomy of Boundary Work in Academic Engineering," *Engineering Studies,* vol. 4, no. 2, pp. 145-169, August 2012.

[2] B. Freeman and K. Gallagher, "Introduction: Taking a Step Back," in *In Defence of Theatre*, Toronto, University of Toronto Press, 2016, pp. 3-20.

[3] W. Kastenberg, G. Hauser-Kastenberg and D. Norris, "An Approach to Undergraduate Engineering Education for the 21st Century," in *Proceedings of the ASEE Frontiers in Education Conference*, San Diego, 2006.

[4] C. Traver et. al., "Fostering Innovation Through Integration of Engineering and Liberal Education," in *American Society for Engineering Education Conference Proceedings*, Vancouver, 2011.

[5] W. A. Wulf, "Some Thoughts on Engineering as a Humanistic Discipline," *International Journal of Engineering Education,* vol. 20, no. 3, pp. 313-314, 2003.

[6] A. Akera, "Liberal Learning Revisited: A Historical Examination of the Underlying Reasons, Frustrations, and Continued Prospects for Engineering and Liberal Arts Integration," in *Proceedings of the ASEE Conference*, Vancouver, 2011.

[7] D. Skorton and A. Bear, "The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine," in *Higher Education: Branches from the Same Tree*, Washington, National Academies Press, 2018.

[8] L. Wilkinson and A. Chong, ""Performing Science: Press Conference as Performative Event," in *21st Conference on Language for Specific Purposes*, Bergen, NO, 2017.

[9] L. Wilkinson and A. Chong, ""Performing Science: Science Communication as Performative Event"," in *Proceedings of the Canadian Engineering Education Association Annual Conference*, Online, 2021.

[10] K. Charmaz, *Constructing Grounded Theory*, Los Angeles: Sage, 2014.

[11] N. Kindelan, *STEM, Theater Arts, and Integrative Interdisciplinary Learning*, New York: Palgrave Macmillan, 2022.

[12] L. Levin, "It's Time to Profess Performance," in *In Defence of Theatre*, Toronto, University of Toronto Press, 2016, pp. 161-177.

[13] J. Butler, "Performative Acts and Gender Constitution: An Essay on Phenomenology and Feminist Theory," in *Writing on the Body: Female Embodiment and Feminist Theory*, New York, Columbia University Press, 1997, pp. 401-417.

[14] A. Chong, *APS321 Teaching Materials*, 2015.

[15] L. Nielsen et. al., "Electric Currents Couple Spatially Separated Biogeochemical Processes in Marine Sediment," *Nature,* vol. 463, pp. 1071-74, 25 February 2010.

[16] J. Schmøkel, "Ground-breaking Danish Research in Nature: Bacteria Collaborate Across Long Distances via Electrical Networks," *scitech.au.dk,* 25 February 2010.

[17] D. Heathcote and G. Bolton, *Drama for Learning: Dorothy Heathcote's Mantle of the Expert Approach to Education*, Portsmouth, UK: Heinemann, 1995.

[18] C. Tomasi, “Simulating an Industrial Experience through Role-play for Students Enrolled in a Rural Mechanical Engineering Technology Program," in *ASEE Conference Proceedings*, 2008.

[19] W. Titley, "Case Study through Role Play and its Effects on the Learning Experience,” in *International Conference on Engineering and Product Design Education Proceedings*, 2007.

[20] F. Benyahia and M. Khraisheh, "Enhancing Student Learning in Chemical Engineering Design via Role Play and Enquiry Guided Learning: a Case Study from Qatar," in *Interdisciplinary Engineering Design Education Conference Proceedings*, 2012.

[21] M. Guerra and T. Shealy, "Teaching User-Centered Design for More Sustainable Infrastructure through Role-play and Experiential Learning," *Journal of Professional Issues in Engineering Education and Practice,* 2018.

[22] K. Visscher, ""Theatrical Technology Assessment: a Role-play Simulation for Transdisciplinary Engineering Education," *Science, Technology & Policy Studies,* 2020.

[23] L. Wilkinson, G. Evans, T. McAlary and E. Moore, "Teaching Engineering Students to be Consulting Engineers: Transdisciplinary Skills Workshops in Project-based Learning," in *Proceedings of the IEEE International Professional Communication Conference*, 2019.

[24] D. Martin, E. Conlon and B. Bowe, “The Role of Role-play in Student Awareness of the Social Dimension of the Engineering Profession,” *European Journal of Engineering Education,* 2019.

[25] W. R. Wilson, ""Using the Chernobyl Incident to Teach Engineering Tthics," *Science and Engineering Ethics,* 2013.

[26] W. Cooley et. al., "Developing Professionalism in the Electrical-Engineering Classroom," *IEEE Transactions on Education,* pp. 149-154, 1991.

[27] N. Doorn and J. Kroesen, "Using and Developing Role Plays in Teaching Aimed at Preparing for Social Responsibility," *Science and Engineering Ethics,* 2013.

[28] L. Wilkinson, *Chain Bacteria Fictional Interview,* 2016.

[29] K. Sanderson, "Bacteria Buzzing in the Seabed," 2010.

[30] Wired Science, "Deep-Sea Bacteria Form Avatar-Style Electrochemical Networks," February 2010. [Online]. [Accessed 8 February 2012].

[31] C. Brahic, "'Pandora' Bacteria Act as One Organism," *New Scientist,* p. 11, 27 February 2010.

[32] W. Frey, "Training Engineers in Moral Imagination for Global Contexts," in *Engineering Ethics for a Globalized World: Philosophy of Engineering and Technology*, Springer, 2015.

[33] B. Freeman and K. Gallagher, *In Defence of Theatre: Aesthetic Practices and Social Interventions*, Toronto: University of Toronto Press, 2016.

[34] N. Ridout, *Theatre and Ethics*, London: Methuen Drama, 2009.

[35] S. Harrison-Pepper, "Dramas of Persuasion: Performance Studies and Interdisciplinary Education," *Theatre Topics,* pp. 141-156, September 1999.

[36] Olive, Interviewee, *Personal Interview.* [Interview]. 1 June 2016.

[37] Seema, Interviewee, *Second Personal Interview.* [Interview]. 27 April 2016.

[38] Amara, Interviewee, *Personal Interview.* [Interview]. 1 June 2016.

[39] Seema, Interviewee, *Personal Interview.* [Interview]. 18 January 2016.

[40] Moe, Interviewee, *Personal Interview.* [Interview]. 1 June 2016.

[41] H. Nicholson, “The Politics of Trust: Drama Education and the Ethic of Care,” *The Journal of Applied Theatre and Performance,* 2002.

[42] T. Cosgrove and J. O'Reilly, ""Theory, Practice And Interiority: an Extended Epistemology for Engineering Education," *European Journal of Engineering Education,* vol. 45, no. 1, pp. 38-54, 2020.

Appendix 1.

1. What is your engineering major?
2. What year are you in your course of study?
3. What experiences in the arts or humanities did you have before enrolling for this course/experience?
4. What motivated you to take this course or get involved in Skule Night?
5. How was your experience in this course similar to, or different from, humanities and social science electives you have taken in the past? Or…
6. How was your experience in Skule Night similar or different to performance activities you have previously taken part in?
7. How did the environment of primarily engineering students impact your experience?
8. How did the application of non-traditional engineering approaches to scientific and engineering content determine your experience?
9. How relevant were the approaches, materials, and overall experience to your engineering education?
10. Did you find opportunities to draw on approaches or tools learnt in engineering classrooms within this context?
11. How do you see your learning in this course or through this experience influencing your activities in other courses?
12. How will you apply the knowledge and experience gained here to your engineering practice?
13. Is there anything about this experience that surprised you? Why?