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Transdisciplinary Approaches in Canadian Engineering Education: Convergences and Challenges

Dr. Kari Zacharias, University of Manitoba

Kari Zacharias is an Assistant Professor in the Centre for Engineering Professional Practice and Engineering Education at the University of Manitoba. She studies intersections and meeting points between engineering ways of knowing, being, and making, and other ways of understanding the world.

Dr. Jillian Seniuk Cicek, University of Manitoba

Dr. Jillian Seniuk Cicek is an Assistant Professor in the Centre for Engineering Professional Practice and Engineering Education at the University of Manitoba, in Winnipeg, Canada.

Ms. Lydia Wilkinson, University of Toronto

Lydia Wilkinson is an Assistant Professor, Teaching in the Engineering Communication Program/Institute for Studies in Transdisciplinary Engineering Education at the University of Toronto, where she teaches courses on written, oral and visual communication

Chantal Rodier
Dr. Laura M. Patterson, University of British Columbia, Okanagan campus

Laura Patterson is an Associate Professor of Teaching in the School of Engineering at the University of British Columbia's Okanagan campus in Kelowna, BC, Canada teaching technical communication courses to engineering students since 2007. She holds a Ph.D. in Technical Communication and Rhetoric from Texas Tech University.

Mr. Renato B. Rodrigues, University of Manitoba

Ph.D. student in Engineering Education at the University of Manitoba.

Prof. Ken Tallman, University of Toronto

Ken is an Associate Professor, Teaching Stream with the Engineering Communication Program at the University of Toronto. Ken's responsibilities include coordinating communication instruction in the Department of Electrical and Computer Engineering and the Department of Materials Science and Engineering.

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Abstract
The Canadian Engineering Education Association / Association Canadienne de l'éducation en génie (CEEA-ACÉG) is a national organization for engineering education practice and research in Canada. Many CEEA-ACÉG members organize into Special Interest Groups (SIGs) to advance their specific interests in engineering education and maintain communities of practice. The Humanities and Engineering SIG is a network of educators, academics, and artists working within or studying the intersections between humanities and engineering.

At the 2022 CEEA-ACÉG annual conference, the Humanities and Engineering SIG facilitated roundtable discussions on four transdisciplinary approaches in engineering education. Over a two-hour period, participants rotated between four tables, focusing on one of the following topics at each table: *Sociotechnical thinking, Sociotechnical leadership, STEAM*, and *Decolonization*.

This paper explores the themes that emerged during conference participants' guided discussions on these four transdisciplinary topics vis-a-vis a constructivist qualitative content analysis of the facilitators' notes and transcriptions of the recorded discussions. Participants did not find common definitions of these terms and sometimes struggled to discuss them, due in part to the relative novelty of the four concepts for engineering audiences. However, as the discussions within and across tables progressed, participants collectively identified challenges and convergences of these transdisciplinary approaches in engineering education. Based on this analysis of a microcosm of the experiences with transdisciplinary approaches of engineering educators in Canada, we conceptualize this process and these topics as "loose concepts" and discuss their power for future research and practice.

Introduction

Academic conferences provide an important venue to connect with the disciplinary community, to share research, and to build new knowledge. These sites of scholarly exchange are often where we explore concepts that are fuzzy or "loose" and through these conversations, generate new understandings or new directions.

The Canadian Engineering Education Association / Association Canadienne de l'éducation en génie (CEEA-ACÉG) is a national organization that brings together engineering educators and researchers at an annual conference. The Engineering and Humanities Special Interest Group (SIG) is one of approximately twelve SIGs operating as communities of practice within CEEA-ACÉG that bring together individuals working and researching within a particular area. The Engineering and Humanities SIG in particular aims to create space for those who study the intersections of engineering and humanities, those who teach at these intersections, and non-engineers who bring their perspectives to engineering environments. As in most large academic organizations, the SIG's membership and engagement is not necessarily representative of the wider landscape of Canadian engineering education. While our SIG aims to reflect the work of scholars, teachers and practitioners at the intersection of engineering and the humanities across Canada, our community is limited to CEEA-ACÉG members who are interested in, and also have the capacity to actively engage with, our smaller community on a monthly basis. CEEA-

ACÉG's annual conference represents a valuable opportunity for us to dialogue with and learn from colleagues who may not be regularly engaged with our SIG.

The theme of the CEEA-ACÉG 2022 conference was "Transforming Learners to Transform Our World." The conference agenda focused on engineers' responsibility to address "wicked" sociotechnical problems, and highlighted the value in bringing together "people who are not afraid to push, bend, twist, and break apart the boundaries of traditional engineering practice" [1]. To address this theme, the Engineering and Humanities SIG hosted a roundtable "collaboratorium" consisting of four discussion topics related to transdisciplinary modes of thought and practice in engineering education. These topics were: *Sociotechnical thinking*, which is an approach to engineering work that recognizes engineering as simultaneously social and technical (e.g. [4]); *Sociotechnical leadership*, which acknowledges the opportunity for engineers to embrace positions of leadership to positively configure the technology-society relationship (e.g. [5]); *STEAM*, which is an educational paradigm that integrates arts practice into science, technology, engineering, and mathematics instruction (e.g. [6]); and *Decolonization*, which calls for radical transformations of educational structures and practices, to recognize, confront, and address the harms of settler colonialism and anti-Indigeneity (e.g. [7]).

Our focus on four distinct transdisciplinary approaches reflected the conference's theme, but also spoke to the sometimes amorphous identity of the SIG itself. The SIG is made up of members working in non-traditional engineering education spaces, including projects and initiatives focusing on sociotechnical knowledge and humanistic engineering, arts and humanities integration within core engineering curricula, communication and teamwork instruction, transdisciplinary integration of leadership, and decolonizing engineering education. Its membership includes engineers who have developed transdisciplinary research and teaching interests; however, the majority of members - including all authors of this paper - are either non-engineers who teach in engineering spaces, or scholars with hybrid identities whose backgrounds include training in engineering as well as in the arts, humanities, or social sciences. Collectively, we viewed the collaboratorium session as an opportunity to discuss topics that are central to our own work with a broader group of engineering educators with varying levels of experience and expertise with these topics.

Our initial expectations were that the collaboratorium might yield a landscape analysis of activities in these four domains to support engineering education practice. This goal informed our planning for the collaboratorium and the dialogue prompts that we devised. Each table had a different set of prompts, intended to encourage participants to reflect upon activities or initiatives supporting these themes within their own institutional or academic communities, as well as to consider how these activities might be better supported in future. However, though some participants reported on activities that they were directly involved in or exposed to, the discussions did not deliver complete inventories of activities within or across institutions. Rather, the conversations took different turns at each table. In each discussion, participants presented multiple interpretations of the terms and prompts, engaging with each of the four central ideas as a boundary concept.

Boundary concepts can be defined as concepts that hold different meanings for different individuals and groups [8]. The looseness of these concepts and their potential to be negotiated and clarified through conversation make them valuable generative tools. These qualities - looseness and openness to negotiation - can also facilitate development of new knowledge through communication and collaboration across disparate groups. Like boundary objects [9], from which boundary concepts take their name, boundary concepts also have social functions: they can "advance specific social interests" through their facilitation of alliances across groups [8]. What emerged from the collaboratorium discussions was neither a landscape analysis nor a set of agreed-upon definitions for the terms that motivated each table's conversations. Instead, the discussions illuminated the variety of ways that these four boundary concepts (*Sociotechnical thinking, Sociotechnical leadership, STEAM,* and *Decolonization*) can be understood, advanced, opposed, and operationalized within engineering education contexts.

This paper provides a snapshot of an engineering education community's negotiation of four boundary concepts by reporting on the themes that emerged from a series of roundtable discussions. Our intention is not to develop definitions of the loose concepts that we discussed. Instead, we present these conversations as a record of a particular moment in time in engineering education in Canada. We demonstrate how a community of engineering educators, researchers, and employees of non-profit organizations and engineering companies attempted to navigate emerging epistemological and pedagogical concepts and new directions in engineering education. We draw from these dialogues to demonstrate the power of loose concepts to elicit multiple perspectives and facilitate meaning making.

Positionality

The Engineering and Humanities SIG is composed of educators and researchers from across Canada working within and between conventional engineering spaces. This session was facilitated by eight SIG members – three from the University of Manitoba, three from the University of Toronto, one from the University of Ottawa and one from the University of British Columbia, Okanagan campus. Our educational backgrounds span Engineering, English, Communication, Rhetoric, Theatre, Visual Art and Design, Science and Technology Studies, and Engineering Education. Our teaching responsibilities run the gamut of transdisciplinary instruction, including communication, science and society, professionalism, team skills, leadership and ethics, and responsibilities as an artist-in-residence, with instruction and supervision at the undergraduate and graduate levels. Our research interests reflect these activities and our career stages span from graduate school to near retirement. We are united by a common interest in how engineering students develop mindsets that enable effective humanistic practice, and we share common values in supporting our students' development of sociotechnical abilities.

The diversity of facilitators is representative of the diversity of SIG members and, in some respects, the membership of CEEA-ACÉG as a whole. The Canadian engineering education community is small in comparison to the United States, and the relative intimacy of its annual conference provides a unique opportunity to bring together diverse perspectives in one common conversation. Within the roundtable discussion we expected that a variety of experiences and perspectives would be represented, though we also anticipated that participants would share our underlying interest in the concepts that we presented and discussed.

Methodology

A series of scholarly dialogues took place at CEEA-ACÉG 2022 during a 120-minute "collaboratorium" organised by the Engineering and Humanities SIG. Over a two-hour period, four groups of approximately 15 participants each rotated between four tables, discussing one of the following topics at each table: Sociotechnical thinking, Sociotechnical leadership, STEAM, and Decolonization. As such, every participant took part in four discrete discussions for approximately 20 minutes each. Each topic was facilitated by two SIG members, who remained at their table for the duration of the collaboratorium, and who are the authors of this paper. (See Figure 1 for a conceptualization of the collaboratorium.)

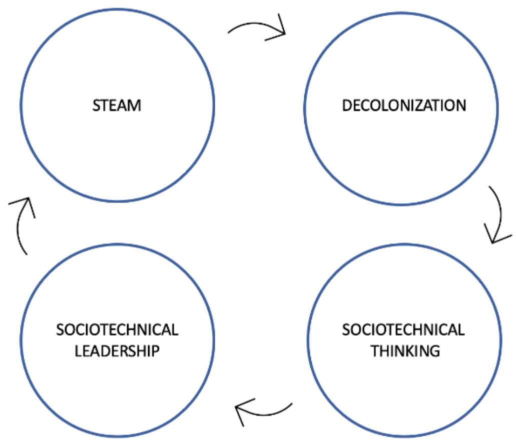

Fig. 1: Collaboratorium tables and topics.

Once groups had moved through all four tables, the SIG chair (one of the facilitators) wrapped up the collaboratorium by inviting one facilitator from each table to share a brief summary of their conversations.

Before attending the conference, the Ethics Board at the University of Toronto was consulted regarding our intention to collect data at the collaboratorium. The Board advised that this was considered a scholarly dialogue, and, as such, an ethics protocol was not required. However, under the Ethics Board's guidance, every person who joined the collaboratorium was asked to sign a consent form during the session that indicated their understanding and agreement that conversations would be recorded and findings from the scholarly dialogue disseminated. We also indicated that if we were going to use a direct quote from a participant, we would contact them to ask their permission. In this regard, for this paper, we do not share full, direct quotations from individuals, but we do use *in vivo* words and short phrases to capture the essence of the discussions in the findings.

Data Collection

Two SIG members sat at each table to facilitate the discussions, and captured key points through note taking and audio-recording conversations. For each topic, four separate discussions were recorded, one for each of the four groups that rotated through each table. This resulted in 16 discrete recordings. As each group sat down at each table, community members were reminded that their conversations would be recorded. The specific approaches taken by the facilitators at each of their respective tables are described in the Findings sections below.

The recorded conversations were transcribed by two undergraduate research assistants at one of our institutions, who signed confidentiality agreements. Facilitators reviewed the transcriptions from their own tables for accuracy, augmenting the transcriptions by checking with the original recordings and their own notes, as needed. The resulting transcripts were then analyzed separately by table facilitators (two facilitators analyzed each transcript, except for the Decolonization table, where one facilitator conducted the analysis).

Data Analysis

A constructivist qualitative content analysis using an inductive approach was chosen for the data analysis [10] [11], which enabled us to identify emergent themes for each of the four topics. This process consisted of three cycles of analysis. In the open coding primary cycle, each researcher examined the data line by line and identified "discrete events, incidents, ideas, actions, perceptions, and interactions of relevance" [10] that were collected as concepts using *in vivo* codes (codes using participants' words). The coding units varied according to the concepts identified, from a few words for simple concepts to a few sentences for complex concepts. In the open coding secondary cycle, we regrouped similar concepts into patterns. This was followed by a third round where patterns were organized into themes and higher level categories. Throughout these processes, we continually referred to the original transcripts to ensure we were capturing the essence of participants' dialogues.

For this paper, we analyzed the table topics separately. Within each table topic, we analyzed the four transcripts separately in the first round of coding, and then categorized the codes collectively across the four discussions in the second and third rounds. Therefore, we have four sections of findings in this paper, delineated by the four table topics, Sociotechnical thinking, Sociotechnical leadership, STEAM, and Decolonization.

This paper focuses on the categories found at this stage of our analysis for each topic. Future work will report the findings from analysis across all topics through a progressive coding method of analysis [12].

Findings: Sociotechnical Thinking

The two facilitators at this table began each group discussion by providing a definition of *sociotechnical thinking* (STT) adapted from [13]: sociotechnical thinking means acknowledging, identifying, and responding to the fact that engineering is inherently both social and technical. We decided to provide a definition based on our assumption that the terminology would be unfamiliar to some discussion participants, and our feeling that it was necessary to provide a basis for the conversation. After presenting the definition and welcoming participants to comment or push back on it during our conversations, we presented three examples of activities from engineering courses that were designed to encourage sociotechnical thinking. Our examples included a set of questions used in an engineering thermodynamics course [14], an exercise from an interdisciplinary design course [15], and an exercise developed by one of the facilitators for use in an engineering communications course. We then invited participants to share their own examples, definitions, comments, and thoughts. In the ensuing conversations, participants expressed their ideas about the definitions of sociotechnical thinking, contexts in which it is useful or required, reasons why it is important, and ways in which it is challenging. Below, we summarize the categories that emerged collectively from the four discussions at this table.

Applications in Current Engineering Practice

Many participants identified examples of their own attempts to integrate sociotechnical thinking into their teaching, as well as other engineering contexts where they believed that sociotechnical thinking would be helpful, or a good fit. While many of these characterizations presented sociotechnical thinking as something new - see below for more on this - others identified applications for sociotechnical thinking within established engineering ways of working, learning or designing. Many of these examples surfaced in the context of design-based courses, exercises, or practices. Participants noted the importance of sociotechnical thinking for thinking through "real-world" or "wicked" problems in a comprehensive way, and discussed the potential for sociotechnical thinking to improve communication between people. Often, this was discussed in the context of students or professional engineers working with and understanding stakeholders - understanding "how people experience a problem" - but this theme also extended to communication within teams. Participants cited sociotechnical thinking as a skill or mindset that could help with conflict resolution and assist engineers working in teams that are multidisciplinary or otherwise diverse.

A New Paradigm for Engineering

In contrast to the above characterizations of sociotechnical thinking as an approach that is complementary to various established engineering activities or processes, many participants implicitly or explicitly characterized sociotechnical thinking as a perspective that is new or foreign to engineering. This occurred both with positive inflections (e.g. sociotechnical thinking as refreshing, as helpful for students' critical reflection on their own work and careers) and negative ones (e.g. sociotechnical thinking as something that is not fostered in industry, and which may be futile to teach if engineers will not be able to practice it in their workplaces). Among the positive mentions of the newness of sociotechnical thinking for engineers, participants highlighted examples from their own experiences of students gaining comfort with ambiguity, and learning to face uncertainty with optimism rather than "despair." In participants' experiences, while students did not always enjoy learning to think in this new way, practicing sociotechnical thinking led them to a deeper understanding of engineering problem definition and solution. In some cases, students' learning was "transformational," leading them to recognize and question their established worldviews.

In some instances, the newness of sociotechnical thinking also rendered it a perceived threat to engineering identity. Participants spoke about students not "getting it," not responding, or responding in ways that reflected dominant engineering methods and ways of thinking, e.g., using workflow diagrams to identify the "correct" ethical response for an exercise that was intended to cultivate comfort with ambiguity. Participants who described their own approaches to teaching sociotechnical thinking often explained how their pedagogies differed from engineering norms.

Value-Laden

Participants described sociotechnical thinking, in different ways, as an approach that was inherently value-laden. Some participants who were instructors themselves were careful to differentiate between their own views on the topic, and what they perceived their students' or colleagues' views to be. In these cases, participants described *other people's* beliefs that sociotechnical thinking is inherently "biased" or representative of a certain set of values, in implicit contrast to *other people's* views of traditional engineering topics or instruction as objective and value-neutral. They articulated their perceptions of their colleagues' concerns about sociotechnical thinking positioning instructors as "moral authorities" in addition to "subject matter authorities."

Other descriptions of sociotechnical thinking as value-laden included explicit connections between sociotechnical thinking and equity, and sociotechnical thinking and safety. In these cases, speakers positioned sociotechnical thinking as inherently good, and as an approach that would necessarily benefit engineering work done in the specified areas. Finally, some participants presented sociotechnical thinking as an approach that is best suited to certain types of people, namely those who are "naturally" more empathetic, or more comfortable with ambiguity.

Micro and Macro Sociotechnical Thinking

The idea of *micro* and *macro* sociotechnical thinking was something that emerged in this conversation that has not yet been widely discussed in the literature. In this sense, micro refers to the day-to-day social interactions of engineering work and how they influence the technical decisions and, as a consequence, the outcomes. This can include teamwork, communication, micro-ethics, empathy, and many other skills and concepts related to interaction between human-beings. In a sense, this can refer to the sociotechnical thinking of an individual.

At the macro level, sociotechnical thinking involves awareness, involvement, and responses to the larger societal, political, ethical, and environmental implications of engineering work. In this case, sociotechnical thinking would refer to the mindset of the profession, while not taking the agency away from an individual sociotechnical thinker.

Awareness of Relationships

The awareness of relationships was a common theme among participants. Building on the micro/macro distinction discussed above, participants expressed awareness of sociotechnical relationships for engineers that were both internal and external to their understandings of traditional engineering work. Internal relationships were those between the social groups involved in the process of engineering work and solutions (engineers, team members, and possibly clients, community, and other stakeholders). This also considers engineers as holistic beings with values, beliefs, and feelings, and how these aspects can impact their "technical" decision-making process.

External relationships were those between engineers/engineering work and the social groups who would use or are directly impacted by that work – the relationships that the Canadian Engineering Accreditation Board's list of graduate attributes describes as the "impact of engineering on society" [16]. We noted that many participants understood sociotechnical engineering only in terms of these external relationships, and did not name internal relationships as part of the sociotechnical process. That is, many people expressed that engineering is sociotechnical because of how "the numbers" are used and their consequences, and not (also) because of the social factors influencing "the numbers." These external relationships also included awareness of the environmental impacts of engineering work, highlighting the importance of factoring "non-humans" into what we understand by "social."

Findings: Sociotechnical Leadership

The four group discussions at the table on sociotechnical leadership were guided by prompts asking participants to consider how they understood the term and how they might value sociotechnical leadership in their teaching. The facilitators began the discussion by framing what we meant by sociotechnical leadership. We included a few examples to ensure consistency of understanding of the terms, e.g. the Tavistock Institute of Human Relations' focus on "sociotechnical systems" as part of the organization's quest to improve human relations in the workplace [17]. We then solicited examples of sociotechnical leadership happening in other areas in engineering education and industry. Each group took the discussion in different directions, but key themes emerged regarding the two parts of the term, considered both separately and holistically.

Understanding Leadership

Many conversations began with a discussion of what was meant by "leadership," separate from the sociotechnical elements of it, suggesting that this alone was a difficult concept to define. One theme that participants consistently brought up, possibly to also wrangle with the concept of sociotechnical, was the need to work interdisciplinarily for good leadership. In fact, some participants suggested that interdisciplinarity is fundamental to leadership. The breadth of this interdisciplinarity was frequently limited to different disciplines within engineering, e.g. leaders should be able to talk about projects with a civil engineer, a mechanical engineer, or an aerospace engineer. Interdisciplinarity was viewed not only in terms of discipline or field of study, but also in terms of people's different backgrounds and cultures. The need for cultural diversity underscored the acknowledged value of inclusivity.

The attention to inclusive leadership emphasized the need for democratic processes in group settings. Rather than top-down leadership, participants called for a de-centred, lateral approach, one that values peer-driven authority rather than the authority of a single person. For these participants, a leadership structure driven by the symbiotic relationship between peers felt like a meaningful alternative to the traditional top-down leadership model.

Frequently connected to inclusive leadership was listening and empathy. In one discussion, a conscious decision to listen was deemed necessary to leadership, and a participant described how choosing to listen instead of following an impulse to act too quickly required "moral maturity". The dialogue of asking questions and listening to others as a form of leadership was discussed by multiple groups. According to participants, empathy and listening allowed leaders to avoid tunnel vision in their own disciplines. Hearing other perspectives contributed towards reframing their thinking on a topic and consequently their ability to choose better actions moving forward.

Some conversations named and discussed dichotomies in leadership qualities. For example, there was a discussion of whether extroversion or introversion made for good leaders, and a similar discussion about specialist versus generalist leaders. Participants expressed concerns about whether the depth of specialist understanding gets lost if there is too much emphasis on the general, while specialization, in contrast, can result in an inability to communicate across disciplines or to multiple audiences.

Understanding Sociotechnical

Similar to the concept of leadership, the discussion surrounding the *sociotechnical* most often grappled with the term's meaning. Most participants focused on the social dimension, indicating that this dimension is too often ignored or undervalued in engineering contexts. One participant emphasized the importance of understanding design as a "values-based proposition" as a way of illustrating the relationship between the social and the technical. Participants broadly agreed that in engineering the social and the technical are intermingled; however, many noted that academic institutions and industry pervasively privilege the technical, relegating the social to a minor role, as a "soft" skill. Most agreed that the intermingling of the social and the technical is essential if we are to solve the more difficult problems faced by our global societies.

The value of interdisciplinarity as a way of understanding sociotechnical as a concept took central focus for all four groups, suggesting that collaboration and connectedness are key to sociotechnical activity. Ethics also emerged as a key consideration, with some participants focusing on interpersonal ethics and some focusing on the ethical responsibilities inherent in the engineering profession.

Understanding Sociotechnical Leadership

When participants linked the *sociotechnical* to *leadership,* the discussion focused on a need to reconsider the key attributes of leadership. While in other elements of the discussion there was a focus on some leadership as individualistic and hierarchical, sociotechnical leadership was discussed as necessarily more democratic and collaborative. One group argued that sociotechnical leadership is an oxymoron, suggesting we need to redefine leadership when considering sociotechnical matters. This redefinition pointed toward leadership guided by open discussion and collaborative consensus.

Replacing the traditional hierarchical leader, participants argued for an equitable, empathetic leader. The concept of humility, particularly disciplinary humility, was brought up at several discussions around sociotechnical leadership. Many suggested that the sociotechnical space, rather than being shaped top to bottom, is decentered and democratic. In this model, the leader shows humility by listening and encouraging rather than by dictating.

Findings: STEAM

The discussions at this table began with an introduction to STEAM, including a definition of the acronym (Science, Technology, Engineering, Arts and Math). Participants were invited to share STEAM initiatives from their institution. Initially this approach was quite systematic as the facilitators attempted to work around the table inviting each participant to speak, but given time constraints the approach soon shifted to a less structured, conversational style. The focus of the introductory remarks, 1) defining STEAM, and 2) asking for examples of STEAM activities, are reflected in the conversations, during which participants worked to make sense of the term and to share examples of STEAM, and less frequently discussed the challenges and affordances of implementing STEAM.

Terminology

Participants grappled with terminology as they attempted to define STEAM; challenged or problematized the existing definition of STEAM; or proposed alternative acronyms or descriptors for STEAM activities. Multiple participants expressed frustration with the STEAM acronym, and the fact that A can seem like an afterthought or addition to the technical focus of STEM. One group in particular discussed the problematics of this acronym and the acronym's implications at length, with a participant complaining that the acronym required disciplines from across campus to move towards a STEM orientation. In response, another group member argued that STEAM is a power orientation for arts and humanities fields, as STEM disciplines often hold the balance of political power on campus. This group volleyed around potential alternatives to the STEAM acronym that might better capture a spirit of collaboration over subjugation, proposing MATES and STEAM MATES as possible alternatives.

Exchanges about terminology reflected the range of understandings of what constitutes STEAM and the amorphous nature of this field. Some participants found the acronym constraining (what subjects does it include or exclude?), while others were quite comfortable expanding their definition of STEAM to encompass all non-technical activities or collaboration. In many instances participants asked for further clarification from the facilitators, and circled back to confirm that their understanding aligned with the rest of the group.

Activities

Participants described STEAM activities to both provide a summary of their institution's initiatives in this area, and to clarify understandings of STEAM. These activities included curricular or institutionalized initiatives, student-led STEAM activities, such as arts integrated approaches to assignment solutions or deliverables, and activities or reference models from outside of engineering faculties.

Many different activities were described by participants, ranging from a capstone video project in which mechanical engineering students creatively pitch their capstone design, to interdisciplinary STEAM oriented engineering design degrees, to an Edward Burtynsky lecture. Many activities reflected participants' enthusiasm for successful initiatives at their home institutions, describing new and emerging programs, STEAM electives, and assignments that invite students to take STEAM approaches.

Others used examples as models for how engineering might better adopt a STEAM approach. One participant, for example, described the arts-integrated nature of the design process in architecture as a model for how engineering might better integrate arts through all stages of design. Participants frequently used examples to help others understand what might be encapsulated by the STEAM acronym. One participant, for instance, used her former work at an arts-integrative elementary school to explain how STEAM approaches function by bringing arts and science together. Another talked at length about the success of First Robotics in adapting a STEM mandate to take a STEAM approach, including business plans and artwork. His expansive view of STEAM activities, including business planning alongside artwork, again underscores the amorphous nature of STEAM. Examples are necessarily used to anchor understanding within a vast, evolving and loosely defined field. It became clear through these discussions that STEAM meant slightly different things to different people, and that these examples helped participants to articulate their understanding of what constitutes STEAM. In turn, the types of examples introduced exposed differences in this understanding.

Challenges
Participants voiced various frustrations about the challenge of including STEAM within engineering curricula. Most frequently, participants cited the challenge of finding space for courses and activities beyond the core, within an already packed curriculum. This difficulty is exacerbated, one participant argued, by the resistance of engineering faculty to eliminate any content, and perceived denigration of non-technical content by faculty.

Participants also voiced counterarguments to the presumed value of these skills and the imperative to make room in these dense timetables. One participant questioned whether we were asking students to do too much, by expecting them to master both technical skills and humanistic understanding at the undergraduate level. He encouraged the other participants to consider the implications of engineering as a four-year undergraduate professional degree, arguing that no other undergraduate degree program expects students to graduate with both the technical proficiency and critical awareness of engineering. Another participant encouraged the group to consider the student voice as we define the curriculum to help them better navigate these expectations.

Other administrative challenges included questions around who should teach STEAM courses and whether instructors should be hired from outside engineering, and the workload complexity of a split course between an engineering and non-engineering faculty member.

Justifications
A small number of exchanges forwarded arguments for *why* we should be teaching STEAM. The challenge of one simple definition for STEAM was again evident in this category of discussion, as two participants seemed to conflate STEAM with creativity, arguing that STEAM should be encouraged in engineering given the importance of creativity in encouraging divergent thinkers. Similarly, two participants advocated for the impact of interdisciplinary teams, presuming that STEAM initiatives are always populated by individuals from diverse backgrounds. Other justifications noted the importance of beautiful design and the value of humanistic approaches in engineering.

Provocations
A few participants used this forum to introduce new ideas or provocations that might call for more significant change at institutional or national levels. Specifically, individuals proposed: 1) a more student-centred approach to curriculum planning at the undergraduate level; 2) an overhaul of the undergraduate engineering degree model, to eliminate the four-year terminal professional degree; 3) an interrogation of how we might train engineers as artists; and 4) new criteria for assessing admission videos to include creativity as an attribute.

Findings: Decolonization
As participants joined the decolonization table, they were referred to these prompts posted on the wall on a large piece of poster paper:

1. What is decolonization?
2. How does decolonization relate to engineering education?

3. How do Indigenous and non-Indigenous (e.g., "western" "global" worldviews) support sociotechnical thinking?
4. Is engineering "objective"?
5. How can we make space in engineering education for decolonized worldviews?

The two facilitators didn't read the prompts to participants or provide a definition of 'decolonization'; nor did we direct participants to begin at the first question. We welcomed everyone to the table and invited them to discuss whatever came to mind. We asked them to make space for everyone at the table. One facilitator helped make that space; the other facilitator recorded the session and made notes on large poster paper at the table. These notes and the dialogues were analyzed for three overarching themes: (1) engineering is…, (2) understanding decolonization and (3) barriers to decolonization.

Engineering is…

Each table group began their discussions within, or by demonstrating the theme, *engineering is*. The first group began with a discussion on the iron ring ceremony, which engineering students in Canada may choose to attend upon graduation, before entering into the profession. The ceremony had been called to the attention of the CEEA-ACÉG conference attendees via Randy Herrmann's keynote address from the previous day, which highlighted engineers' role as colonizers [19], and at a conference workshop called, "We need to talk about Rudyard Kipling: On the origins of the Ritual Calling of the Engineer in an age of reconciliation", that some participants had attended. One participant commented on the "dual symbolism" of the survey chain, which was/is considered an engineering "feat" and was a mechanism for colonialism as engineers used it to create reserves and separate Indigenous people from growing settler cities.

The second table began discussing engineering as a subjective, reductionist system, and how engineering education is taught to our students through a dominant positivist paradigm [20] of which students are not made aware. One participant remarked how engineering trains students to draw a circle around a "problem" and focus exclusively on what is within that circle, which inhibits sociotechnical thinking. The group discussed how "engineering as objective" thinking is advanced by the broader community. This positivistic mindset was identified as a barrier to decolonization, with colonialism "embedded" in the culture of engineering.

The third table initiated their conversation with questions, asking to what extent the notion of the "engineering expert as a leader" was a western idea. They discussed how we offer land acknowledgements (e.g., in engineering education) and then continue to "use the land for settler purposes", referencing western colonial notions of property ownership. This followed with a discussion on how learning in this space can perpetuate dangerous generalities and dualistic thinking, such as Indigenous "stasis" versus western "progress". Engineering, conceptualized as "bigger, better", was discussed as perpetuating colonialism. One participant followed this with the literal and metaphorical example of basket weaving, which was a global Indigenous technology and yet framed as a pejorative. They demonstrated basket weaving as "an amazing" skill, likening it to "sophisticated repair" with "structural integrity"; it was linked metaphorically to the values of "maintaining" and "preserving hard-won knowledge" and "a commitment to a system that is working". The group commented on how we don't teach design for "sustainability," for "repairability," or "use of sustainable materials" in engineering education.

They questioned whether, considering western societal values, decolonization would be possible in engineering.

The last table began with an enactment of engineering, with one table member declaring they did not know the “answers” but warning that we must find these answers quickly. This was neutralized with the introduction of Robin Wall Kimmerer’s book, *Braiding Sweetgrass* [22], and a comment on how Wall Kimmerer was disconnected from the land through the western institutional education system. One group member spoke about how we cannot understand decolonization without knowing colonization, as we “won’t appreciate what we’ve lost” or what “is being sought.” The word “colonialism” was identified as “part of the problem” because it gives people permission to excuse it to history, and say, “that wasn’t me”. The table discussed how to “interrupt” this ongoing process. Engineering education was identified as a colonial system where we celebrate “engineering miracles” and accomplishments “without seeing the cost”.

Understanding Decolonization

Participants accessed decolonization by first unpacking “colonialism”, which they understood in a variety of ways. They acknowledged the history of colonization on Indigenous Peoples and its continued impact and effect. Some participants spoke about colonialism as it manifests in/through engineering, discussing engineering education as a system of power and expressing dominant modes of scientific practice as very colonial, western, objective, and as such, limited. Some challenged the paradigms of “engineering expert” and “leader,” and there was critical discussion on where education comes from and who our valued or trusted sources of knowledge are.

The subsequent discussion of decolonization centred on approaches for decolonizing the university: generating safe spaces; inviting other voices in; pulling back on forcing one value system and welcoming different viewpoints to exist together; and integrating Indigenous perspectives into curricula. Participants discussed facing privilege by grappling with white supremacy and white fragility, and described their own understanding of how inequity is built into colonial systems, which can exclude individuals, their knowledges, their cultures, while allowing others to benefit. Participants discussed challenging our understanding of relationships and the importance we place on relationships as engineers. To challenge these established structures and relationships, participants suggested challenging our schedules and time management, deconstructing organizational hierarchies, building new relationships with stakeholders, and learning how to talk to people who don’t think like engineers. Overall, participants argued that disentangling the colonial assumptions inherent in engineering was required for engineering to be more sustainable, contending that sustainability involves knowledges and wisdom that are not currently within our system.

Barriers to Decolonization

The positivistic mindset of engineering and engineering education was discussed as a barrier to decolonization. Participants observed how engineering values revolve around evidence and authority and noted that engineering education can take shelter in abstraction, teaching the theoretical rather than the application, and not teaching about values or judgements. This engineering value system was contrasted with Indigenous knowledges and value systems.

Capitalism as an engineering value surfaced as another barrier: participants argued that profit, innovation, and newer, bigger products are emphasized by dominant engineering design practices, at the expense of sustainability, reparability, and maintenance. There was also recognition that "colonization", as a word and concept, implies the past, and perpetuates a "that was 150 years ago", "that wasn't me" mentality, which is another barrier to decolonization. Participants questioned how we break this cycle without expertise.

Discussion

We observed a range of knowledge, experience, and comfort levels with regard to the four topics. There was a consensus across the groups and tables on the need for such conversations and thinking. However, a sense of uncertainty pervaded many of the discussions, and we noted occasional instances of resistance as well. This was particularly evident in the discussions on sociotechnical thinking and decolonization, during which some participants were evidently reluctant to speak, or shared their thoughts with multiple caveats or hesitations.

Some participants mentioned that engaging with sociotechnical thinking is not "who [engineering instructors] are." This included the idea that engineering faculty are not equipped to teach sociotechnical thinking, as well as arguments that students will not engage with it. Some participants also offered strategies to overcome this perceived barrier, including reframing sociotechnical thinking as "professional skills." Sociotechnical thinking as a threat to core technical engineers was offered as a deeper reason for this uncertainty, discomfort, resistance, or avoidance. That is, as sociotechnical thinking introduces "new paradigms for engineering", it threatens a core aspect of engineering identity: a purely technical profession that is non-political and value-free and is not directly responsible for the impacts of technology.

Similar barriers were discussed with decolonization. Participants acknowledged that the widespread belief in engineering objectivity and the roots of engineering in western science and capitalism make it very difficult to decolonize, and, for some, render decolonization a threat to (traditional, dominant) engineering identities. However, unlike in the sociotechnical discussion, participants did not dwell on decolonization as a threat, nor suggest strategies to make it more palatable for engineers. Everyone communicated the importance of decolonization, particularly in understanding the negative impact of colonization on Indigenous peoples in Canada and the colonial foundations of engineering and engineering education. If participants disagreed, or felt differently, this was not overtly expressed. There were some isolated instances of conversations that 'othered' people, or decolonization as a 'problem to be solved, and quickly.' But these few moments did not evolve into larger discussions; rather, they dissolved in the face of countering points or ideas that reframed the collective thinking. Participants expressed a complex and varied understanding of what decolonization is, and could be, and there were some ideas of how to at least start decolonizing engineering education.

Participants generally appeared to agree that integrative opportunities in engineering are valuable. This was experienced in the discussions on STEAM, where participants argued that we should be working to infuse arts into the curriculum to support non-technical skills development, specifically in creativity and communication, as well as to encourage interdisciplinary collaboration. The importance of integration also manifested in the sociotechnical leadership discussions. Because sociotechnical leadership requires, as was suggested by several participants, effective management of the interactions and interdependencies between people, technology and the broader social contexts within the community, it involves intense complexity and systems thinking. Many suggested that humanistic perspectives are necessary for this approach to leadership. This is because it involves understanding the social and technical systems within the community impacted by a project and using that understanding to make decisions and implement changes that improve design. Sociotechnical leadership also requires considering social, cultural, economic, and other impacts on community members.

In many ways, all of these concepts require a paradigmatic shift in thinking from "traditional" engineering. They are complex, they can be uncomfortable, and they centre human relationships and affective domains. They require transdisciplinarity. Having these conversations within engineering education is valuable because it gives educators and researchers space to listen, reflect, and access this thinking. We observed - in ourselves as well as in others - an internal struggle to avoid 'solving the problem' or attempting to reach consensus on definitions, and instead to practice listening and exploring our thinking through dialogue. These are topics that are relatively new to engineering culture on a broad scale. We must learn how to dialogue, stretch, and challenge our thinking and our values without being prescriptive or judgmental.

Having these conversations within engineering education is also valuable because they create space for boundary concepts to remain fuzzy [8]. There is power in loose concepts to facilitate the development of alliances, which may permit the construction of new knowledge, and in this case, potentially new pedagogies. Convergence is not always necessary or desired. Loose concepts can make interactions between different epistemological cultures possible. Overall, the Humanities Special Interest Group is itself a loose concept. This is a good thing, although it can be difficult to manage. This collaboratorium is a microcosm of the way in which people and groups that are affiliated with, but not necessarily inherent to, engineering, can interact. There is power in the transdisciplinarity that engineering education could and should be.

Conclusion

This paper presents a snapshot of Canadian engineering educators' conversations on four loosely-defined topics - sociotechnical thinking, sociotechnical leadership, STEAM, and decolonization - at a specific moment in time. Presenting these initial categories and themes is meant to provoke our thinking on how our engineering education communities are conceptualizing these difficult constructs, and where this thinking will lead.

We recognize that this work is messy: people have different ideas and approaches and are at different places in their thinking about these ideas. Conversations on these topics are currently growing in Canada, and through them we can learn how community members are at different places on the knowledge spectrum, and in the processes of decolonizing, reframing or broadening our thinking. We also recognize that our position as a humanities SIG within a broader organization of engineering educators influences these conversations and our interpretation of the data, as well as the sorts of engineering educators who would decide to participate in our collaboratorium. Because our day-to-day work within engineering involves the humanities, we tend to privilege STEAM and the sociotechnical over the purely technical, and our discussion of the data may reflect that. Because there is no Indigenous representation among the facilitator/author group, the discussion around decolonization is interpreted through our perspectives as settlers. Understanding our positionality helps to provide context to our findings here but will also be a place for our SIG to explore in the future with this work. Though some diversity of thought, experience, discipline, age, gender and race was present in this collaboratorium, the group largely remains a western-centred, western-educated group. As such, we are on the inside. These dialogues need to continue with - start with - more of us who are outside this space.

This paper presents the beginning of our work with this data and our exploration of this scholarly dialogue as a methodology. In our ongoing work, we will continue to explore how we can make space for conversations and ideas to foster transdisciplinarity, sociotechnical thinking and leadership, and decolonization in engineering education. We will also continue to explore the intra-group dynamics in this data;, and specifically, how the social element and structure of the collaboratorium and these four topics enacted these group dynamics and coalesced through these table discussions. In doing so, we aim to learn who engineering educators are in the CEEA-ACÉG community, what they are saying and not saying, and how to continue to foster increasingly diverse groups and dialogues in engineering education.

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