Implications of Engineering and Education Professor's Problem-Solving Mindsets on Their Teaching and Research

Ms. Alexis Suzanne Capitano, Colorado School of Mines

Alexis currently attends the Colorado School of Mines. She is a senior majoring in Electrical Engineering and simultaneously pursing a Masters of Science in STEM Education with a planned graduation date of December 2024.

Ryan Miller, Colorado School of Mines
Dr. Kathryn Johnson, Colorado School of Mines

Kathryn Johnson is a Professor at the Colorado School of Mines in the Department of Electrical Engineering. In the Fall 2021, she visited the University of Calgary as the Fulbright Canada Research Chair in STEM Education.

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Abstract

Engineering has a reputation as a "problem solving" field, and many aspects of engineering education aim to prepare its future professionals to solve problems they may face in the real world. However, often the problem defining (or problem identifying) phase of the problem-solving process is less visible, which has the potential to bias solutions. This paper seeks to understand the qualities of a problem-solving mindset that are illustrated in faculty interview data and how these mindsets impact the interviewees' academic responsibilities, especially with respect to teaching and research. Both teaching and research aspects have implications for engineering education. The interviews we analyzed included two faculty in a school of engineering and two in a school of education at a public university in Western Canada.

Introduction

In modern day engineering education, there is much greater appreciation of qualitative research and interest in understanding the individual narratives of research participants. The field of engineering education research has gone through many evolutions since its beginnings in the 19th century. Mainly, there has been a shift in focus from improving quantitative productivity of students to a more qualitative understanding of the experience of an engineering classroom. The shift towards qualitative research has been accomplished through incorporating aspects of sociology, anthropology, and ethnography into the research process [1]. This drive toward more holistic understanding motivated our research team to try and understand the role problem-solving mindsets play in the work of engineering and education faculty. Awareness of multiple possible mindsets when approaching problems could help educators be more effective in the classroom. Further, if educators displayed a noticeable preference for a particular mindset when approaching issues in the classroom, helping them to understand this tendency could help raise awareness of potential biases that may have stemmed from their previous educational experiences. A better understanding of their own mindsets and biases could help educators to better understand how much time to spend in each phase of problem solving when addressing issues in the classroom.

In this paper we seek to understand some of the qualities of problem-solving mindsets expressed by professors from engineering and education backgrounds. To do this we analyzed a set of interview transcripts from interviews previously conducted with faculty affiliated with engineering and education at a public university in Western Canada. From this data our research

team performed a narrative analysis of four of the interview transcripts, two education faculty and two engineering faculty. We chose narrative analysis to try to preserve the authenticity and best capture the elements of problem-solving expressed by each interviewee throughout the entirety of the interview [2].

Our research team was interested to see how problem solving mindsets would or would not manifest in our analysis of these transcripts. We assumed that the different training inherent in the two disciplines could lead to different mindset expressions. We sought to answer the following questions:

RQ1: What qualities, if any, of a problem-solving mindset are illustrated in the four professors' responses to a set of semi-structured interview questions?

RQ2: How do these mindsets appear to impact their academic responsibilities (teaching and research)?

The goal of this paper is to examine the impacts of different mindsets on the way educators approach their teaching and research. Although the results from this four-person study are not generalizable to engineering or education faculty more broadly, gaining a better understanding of the problem-solving-relevant mindsets of these individuals can add greater detail and understanding to concepts explored in previously established literature.

This paper is organized as follows. In the next section, we describe the background and literature relevant to our study. Next, we describe our methods for collecting and analyzing the interview transcript data. The Findings section describes the mindsets and themes we found in the data based on the analysis process. It is followed by the Discussion and Conclusions, in which we comment on the mindsets and synthesize our big-picture takeaways, as well as remarking on possible future work.

Background

An important facet of education to consider is the mindsets of teachers and students. A multitude of studies have shown evidence that student's mindsets have a large influence on their educational results [3], [4], [5]. People with growth mindsets have shown more motivation in their class work and better grades than their fixed counterparts [6], [7]. In light of these studies, it has become important to understand how to foster these growth mindsets in the classroom. In Wacker and Olson's university-wide study, it was determined that teacher's own views have an impact on academic achievement. They found that classes taught by an instructor with a fixed mindset resulted in achievement gaps that were twice as large as those taught by teachers with a growth mindset [6]. This impact is further confirmed by the findings in Oduwole's paper where he mentions that "teachers' beliefs are frequently taken over by their students" (p. 115) [7]. These studies demonstrate the impact of a teacher's mindset on a student's learning, so gaining insights into professors' mindsets is shown to be valuable. Our paper explores mindsets that are common to engineering and education faculty and related literature to each will be discussed.

Engineering is a profession centered on creating a design, typically one that will address or solve a problem. Being an engineer has become strongly associated with a problem-solving mindset. Faculty members commonly described engineering as problem-solving itself [8], [9]. The design

process is so permeated into the engineering profession, there are many common jokes that revolve around an engineer solving a problem in the "engineering way," while missing potentially simpler, non-technical approaches to solving the same problem [10]. The engineering way of solving a problem can best be described by looking into the engineering design process. Engineers tend to have six habits of mind that help describe their way of thinking and that model the ideas used in the design process: systems thinking, problem-finding, visualizing, improving, creative problem solving, and adapting [11]. This process is typically focused on understanding enough to make a productive change to a situation rather than primarily seeking to understand the root cause.

The problem-solving mindset is also prevalent in engineering education, but there are critiques that assert the curriculum isn't fully representative of the profession [12]. In the UK, MacLeod suggests that engineering education is geared toward developing an academic mindset rather than an engineering mindset [13]. He mentions that the education that engineers receive doesn't help their ability to innovate because it centers around a theoretical approach where problems are well-defined. This approach differs greatly in comparison to the engineering practice, where engineers must often solve under-defined problems [13]. In this instance he believes the issue with engineering education is that it takes an academic approach that "limits the development of tacit knowledge," (p. 26) mainly limiting the nurturing of associativity and intuition [13].

While we discovered a coherent group of papers studying engineering mindsets that were relevant to our research questions, it was more difficult to place education mindsets within the existing literature due to the breadth of the research. We also recognized that the education faculty whose transcripts we analyzed came from substantially different backgrounds that likely influenced their mindsets, so we examined mindsets across different disciplines.

One mindset that we examined is the mindset of a scientist. Scientists aim to observe, infer, classify, predict, and hypothesize [14], [15]. In this sense the scientific method is based upon considering all of the different factors and data to form a conclusion. Another important aspect of science is that the "Scientific method does not insure the satisfactory solution of the problem...any more than it insures the construction of an adequate hypothesis for the research problem" (p. 238) [16]. This statement suggests that a scientist's mindset is primarily focused on the problem definition stage of problem solving.

The problem-solving mindset is also evidenced in an expansive range of disciplines through their academic writing. It is apparent in social sciences, such as psychology, through their professional papers and educational practices. Psychology textbooks emphasize problem definition while researching, and students are often tested on how to define problems on their exams [17]. Problem-solving was also evident in more literary disciplines, in which their papers commonly attempt to describe a phenomena. These papers cover more diverse topics and the problem-solving process is harder to decipher to those outside of the field [17]. As Toulmin states, "the crucial element in a collective discipline...is the recognition of a sufficiently agreed goal or ideal, in which common outstanding problems can be identified" (p. 364) [18]. This quote suggests that each discipline will have its own problems, and therefore its own methods of dealing with those problems. The literature shows the prevalence of problem-definition in academia regardless of discipline.

In the beginning of this study we expected that the problem-solving mindset would be evident in the responses from the engineering faculty, but we were uncertain what mindsets would be evident within the education faculty. Based on preliminary analysis and the literature on the engineering "problem solving" mindset, we expected to find differences in the ways in which interviewees with training in engineering and education describe problem-solving. While only studying a few individuals, we hoped to provide a richer description of the ways in which problem-solving is described by people from both fields that can complement the existing literature on the topic. A better understanding of engineering problem-solving mindsets – and possible alternatives from a different field – could shed light on engineering teaching, learning, research, and practice.

Methods

The paper is based on analysis of interview data that was collected in 2021 at a public university in Western Canada. As part of a larger project, this paper's third author conducted semi-structured interviews with faculty and postdoctoral researchers from both the School of Engineering and School of Education. As can be seen in the Appendix, interviewees were asked about their perceptions of macroethics and social justice, their research, and local contexts in sessions that ranged in duration from 30-90 minutes. Seventeen faculty and postdocs were interviewed for the original project, nine of whom held positions in the university's school of education and eight in the school of engineering.

Interviewees were recruited by email using a combination of publicly-available information (e.g., faculty web sites, university publications) and snowball sampling. Some interviewees chose virtual interviews and others chose in-person interviews. In both cases, the interviews were recorded and then transcribed. A professional transcription service was used for the in-person interviews, whereas Zoom's automatic transcription was used for virtual interviews. In both cases, the interviewer checked the transcripts for accuracy prior to analysis and made light edits for clarity, but did not change the format of the transcript. The interviewer also removed all identifying information prior to analysis.

The four transcripts selected to be analyzed for this paper were based on interviews with two engineering faculty (pseudonyms: Leo and Tara) and two education faculty (pseudonyms: Lisa and Summer). They were chosen based on review of responses to two isolated questions from the interview protocol that suggested mindsets relevant to problem solving. To better understand the bigger picture of mindset in the transcripts, we sought to understand the interview as a whole. We therefore followed a procedure inspired by narrative analysis.

Humans naturally use stories to deconstruct and understand the world around them [19]. By reconstructing that narrative in a research setting, researchers can get a more complete picture of the individual's mindsets. This understanding is especially important in engineering education research where the goal is often to understand a facet of an individual's experience [20]. There are many factors that influence a person's perspective: culture, religion, geographic location, etc. Narrative analysis provides a way to bring in sociological information that may otherwise be lost through other methodologies. This holistic approach helps to improve the quality of our analysis [21].

Narrative analysis has been used in engineering education research to understand a variety of

topics relevant to the field [2], [22], [23], [24]. For example, Walker used narrative analysis of interview data to understand complex engineering identities [24]. Since our goal was to understand qualities of the interviewees' mindsets related to problem-solving and how these mindsets impact both teaching and learning – a complex relationship – it was important to consider the interview as a whole. Although interviewees were not asked specifically about their mindsets, we found evidence of mindsets throughout the interview data, supporting this approach.

Our "Findings" are therefore reported as summary "stories" of each of the four transcripts, quoting from the transcripts to illustrate key points and building connections to problem-solving mindsets and how they shape the interviewees' interactions with their students.

The data collection and analysis steps followed human subjects research ethics guidance from the university at which the interviews were conducted and the authors' university.

Context

Several contextual factors undoubtedly shaped the interviews that were analyzed for this paper. First, a COVID-19 resurgence drove many campus activities back to the virtual realm. Second, Canada's Indigenous people were frequently in the news. The nation's Truth and Reconciliation Commission ,which was formed as a result of growing awareness the horrific situation with Residential Schools, was frequently in the news [25]. Canada recognized Sep. 30 as the National Day for Truth and Reconciliation with a number of educational and recognition activities. Perhaps related to all of the news and events, it is not surprising that many interviewees mentioned Canada's Indigenous communities when asked questions related to macroethics and social justice. Similarly, many of the identified "problems" in the interviews were relevant to these current events and public conversations.

Analysis Procedure

To perform our analysis, we created a template consisting of preliminary instructions

1. Read the anonymized interview transcript in full, probably multiple times
2. Highlight or make note of important sections (on 2nd or 3rd read-through)

and a set of sections for each reader to complete to better understand the interview as a whole. The template was revised between the first and last transcript analysis to help us focus our analysis; the final version contained the six items shown in Figure 1.

All three authors of this paper read and filled out this analysis template (items 3-8 in Figure 1) for the first two transcripts we studied. After discussing our levels of agreement and interpretations for these to improve inter-rater reliability, two authors each read and filled out the analysis template for the remaining two transcripts. All three authors discussed the individual memos for each of the four transcripts, seeking to determine key points of agreement or discrepancy related to our research questions. Finally, each of us drafted a combined memo for 1-2 of the transcripts, forming the main content for the Findings section of this paper. We then further discussed and

3. Summary (1-2 key points)
4. Important themes/concepts table to fill in with evidence and brief narrative

Concept Name	Instructions
Mindset	If possible, be more descriptive than just "problem-solving," e.g., "growth mindset," "problem identification," etc. If relevant, particular problems could be mentioned here.
Illustrative Quote(s)	Add 1-3 quotes that illustrate this mindset. Include page numbers.
Prevalence	1-5 scale (with 5 high) and very brief description
Narrative	Write a short paragraph (3-6 sentences) summarizing the concept and its evidence etc. in the interview. These could form the foundational outline for the eventual paper. Quotes not needed here since they are above.

5. Story progression (1st point, 2nd point, etc.)
6. Comments on flow
7. Language used (common words and phrases relevant to the research question, point of view and voice)
8. Possible biases (of the reader)

Figure 1: Template for individual analytic memos including our "concept table" (step 4)

edited the combined memos for clarity and to focus on the research questions for inclusion into this paper.

Findings

In this section, we describe the narratives from our four transcripts (Leo, Lisa, Summer, and Tara) with a focus on how they relate to our two research questions. These subsections, provided alphabetically by pseudonym, are derived from the memos we wrote from our individual analysis templates (see Methods). Points of commonality and discrepancy, as well as implications for engineering education, follow in the Discussion and Conclusions section.

Leo (Engineering)

Leo's interview transcript narrative jumped back and forth between two key concepts: problem definition/solving and entrepreneurialism.

Leo began by describing his research interest related to energy and climate change, a clear example of defining and seeking to solve a problem. He highlighted how the energy transition differs from his view of previous engineering challenges because it requires societal buy-in within the engineering process, not just at the end.

> "For a long time in engineering, we trained engineers to go solve problems, but without having to worry too much about 'well when it's time to deploy we'll just go

> and deploy.' And that was often the case. That's not the case so much anymore, and certainly not in the energy transition...The other theme that's occupying me is how do we, especially on the engineering side of campus, of society, include, both in the framing of what is the problem we're actually trying to do to be solved, include the societal perspective and social innovation and the framing the problem and designing solutions to the problem so that the societal buy-in at the end of the process is baked into the process rather than an afterthought." (00:05:47–00:07:00)

Based on this quote, this "societal buy-in" as an integral part of engineering problem solving throughout the entire process implies a shift in Leo's view of engineering, a change that could substantially impact both engineering education and practice.

Leo expressed that while he felt supported at his university, he was also aware of structural elements common to academia as a whole that may prevent junior faculty from feeling the same level of support, especially if misaligned with the status quo. These elements included not being credited for collaborative efforts when going up for tenure and not having the time to devote to branching out beyond their discipline. Speaking of interdisciplinary research integrating social and technological innovation, Leo said

> "This needs to not be something that people are doing off the side of their desk as one more thing, as is so often the case with academia. So, it's to recognize that we need a structure that enables folks who are serious about doing this [non-traditional research], to be able to not do some other things for a while, while they engage in doing this." (00:10:55–00:11:10)

In an example of a later phase of a problem-solving mindset, after defining this structural problem for engineering faculty, Leo went on to suggest possible solutions to encourage more faculty to get involved with cross-disciplinary activities.

While Leo said he was unfamiliar with the term macroethics, he proposed the definition "...how we manage connections and relationships between various communities in what is a remarkably heterogeneous country." (00:16:43–00:16:50) Leo expressed that the goal of macroethics and social justice should be to "enable a more socially just solution to a variety of challenges" (00:17:53–00:18:09). He then connected this goal back to the energy transition in yet another example of his problem solving mindset: trying to relate new information back to familiar information to solve a problem.

Leo frequently speculated on who benefitted from his work. He brought up ideas of energy equity, energy justice, and energy sovereignty, stressing the importance of the voice of the community when developing a technical solution: "Because if some people think the problem to be solved is 'A' and I show up with a great technical solution to 'B,' guess what? The folks who are looking for 'A' are going to say 'What?"' (00:22:49–00:23:04) This identification of stakeholders and the solution environment illustrates problem definition.

Leo went on to describe one of the things that attracted him to the university in the first place: institutional support of leadership positions related to things like "social innovation" (00:34:20–00:34:27). Leo actively suggested revisions for such positions, again illustrating his problem-solving mindset.

Finally, Leo spent a sizeable amount of time discussing how innovation plays a role at the university, in his work, and with his students. He described the city in which the university is located as an "Innovation Ecosystem" (00:37:05–37:09) and explained how groups are trying to make discoveries that would enable novel solutions to a variety of problems.

> "Asking interesting 'why' questions, we get funding to figure that out. And by having a mindset of pushing it out there, and getting 'a thing' is part of it, coming back to the social aspect of this, what I think we can have much more impact doing, is not just the invention, but the invention mindset. We need to be producing students, especially engineers, who have rediscovered their innovative, child mind, which, by the time we're done with them we've pretty much beat all their creativity and innovative thinking out of them." (00:40:37–00:41:14)

In this quote, Leo clearly outlined the importance of creative and innovative mindsets in engineering that can ultimately contribute to better problem solving. Beating "all their creativity and innovative thinking out of them" certainly undesirable. He went on to describe how students are hungry for opportunities to innovate, but often don't get the opportunity to do so once they enter industry.

> "You usually don't get to start off in the innovation division if in fact, they have one. Once you've been there 20 years you might get to be one of the people who gets to scout for technology to bring in, but you never get the chance to do it yourself. Okay so [our university] started a course, we piloted it...which attempted to give that experience, hands on experience, guided towards innovation, to undergrads. And it's a delightful thing...it is exactly what we need to inspire these [students]." (00:47:56–00:49:15)

This quote provides another example of Leo seeing a problem and trying to solve it, with obvious curricular implications for engineering education at his university.

Lisa (Education)

Lisa's interview transcript narrative followed the overall structure of the interview protocol, connecting repeatedly back to interrelated themes of social justice, equity and inclusion, macroethics, fixing structural factors, and authenticity. We observed both problem-defining and problem-solving mindsets related to these themes.

When asked whether macroethics and social justice play a role in her teaching and research, Lisa made clear that she was driven to facilitate change: "my research is both about trying to address structural change and also empowering people who have been marginalized from experiences and opportunities" (p. 3, 00:05:52-00:06:12). Further, she was driven to raise awareness: "And also making people, be more aware of those structures and how – because that's the way that change happens is with increased awareness." (p. 3, 00:06:32-00:06:41)

In response to the interview question about the impact of the local context, Lisa described how the Provincial leadership reinforced existing structures that can be harmful to EDI. She explained that, at the K-12 level,

> "...there's this curriculum that's being rolled out that's very harmful because of the way that different aspects of history and culture are just being absent from the community, I mean from the curriculum, like the history of Indigenous people in residential schools, and there's nothing really about Black [residents of this province] and their role in settling this land or whatever, so there are a lot of harmful things that are happening, and I do see that there's a push back..." (p. 5, 00:11:24-00:12:14)

Continuing on the theme that STEM education system are themselves inequitable and unjust and what can be done to address that, in response to the next interview question, Lisa explained that

> "...there's a lot of things that structure why STEM education is the way that it is, or STEM in general, so I think it's about being vigilant and constantly questioning those things that are taken for granted, like, for one, the objectivity of science or neutrality of science, and taking a stance that it's always about critically questioning who's benefiting, who's being harmed, in what ways is this not neutral, thinking about the ways that science is gendered, the way that it's racialized and the way that there's a heavy reliance on quantitative data in many spaces and not necessarily the qualitative, observational experiences of not only Indigenous people, but also people that have everyday interactions with nature and other phenomenon, so I think with science there's definitely a lot that that needs to happen at many different levels." (p. 6, 00:13:08-00:14:15)

Clearly, these structures tie back to equity and social justice issues and define different aspects of the structural problems in STEM education that Lisa had defined. Lisa alluded to a potential solution, noting that "there's a lot of work in different informal science on projects that are really looking at expanding what counts as scientific knowledge and knowing. So hopefully that will also eventually make its way into formal science" (p. 7, 00:16:04-00:26:23), but didn't describe her role in that particular work.

Summer (Education)

In her interview transcript, Summer described many elements of community, decolonization, and systems, which we found to be key themes in her narrative. Of the three, community appeared first in Summer's description of her work. She said

> "And also I'm very interested in community engagement. And kind of how community engagement is looked at from an individualistic lens, a neoliberal lens, which continues to be quite exploitative and colonizing. And so a lot of the hope of my research and teaching is to, how can we envision what we think and what we do in a communal way? So that we can be more socially responsive and no longer work from a perspective of dominance and minoritization." (p. 1)

In this quote, Summer described research and teaching goals with an aspirational viewpoint to promote community and social responsiveness and minimize the perspectives of dominance and minoritization. In this example, the problems Summer defined are exploitation and colonization, and the solution she proposed is to change thinking to approach these problems from new

perspectives.

This quote also connects to the second theme of decolonization, which is closely tied to structures and systems of power. Proceeding to the next part of the interview, Summer again mentioned community engagement and decolonization as concepts that many people talk about but don't actually act on:

> "So you can talk about community engagement, EDI, and decolonization, but what are you actually doing, right? So at [school of education], I see a lot of evidence of that [doing]. I think we have a very strong group of peers that work together that kind of hold each other up and collaborate quite a bit. At the university level, I see that in internationalization with the intercultural bit. And with the Indigenization and decolonization. I see that that's very strong compared to other universities." (pp. 2-3)

In this example, the problem is people talking without acting, and the solution is collaborative work with peers that supports action, which Summer described as a strength of the university and among her colleagues.

When asked about macroethics and social justice, Summer connected them to systems and the continuing problem of injustice.

> "...we [disciplines] are making this very cut and dry decisions about who gets access to things and who doesn't. And what is the system of justification for the perceived injustice...So we are making those decisions, we are interfering with peoples' lives...Because I think that once the disciplines infuse that kind of [disciplinary] knowledge into this public domain, then it kind of gets a life of its own and how it's picked up by lawmakers and politicians, and then how it's actually legislated then it becomes another can of worms, right? But then it loops back to the kinds of practices that we're teaching that we are holding as the gold standard of our disciplinary practice. So there is this loop here, right? That keeps going." (p. 3)

In this quote, Summer described the feedback loops in systems that perpetuate injustices, observing how academic disciplines can contribute to political dis-empowerment but that faculty can help to prevent that via their teaching practices. Returning again to helping her students to become problem solvers, Summer said "in my teaching, I tried to think of ways in which I create the opportunities for students to really enact what they are learning, so how can I really change the kind of pedagogy that actually sustained this kind of neoliberal work, colonial logic, right?" (p. 5) Again, she described how she was engaged in problem solving against problematic systems that have harmed some communities.

Summer returned to these concepts of community, decolonization, and systems repeatedly through the rest of the interview, interweaving problem definition and her work to inspire students to solve problems. When asked about her university's support for macroethics and social justice, she first provided her philosophy of ethical community engagement

> "I think that it is a reciprocal relationship where I think those who are entering a particular community are first building a relationship, knowing the community, being part of the community to then see what they have are gifts, and how we can help a particular... And not help, in the sense of, instead of the word help, maybe a better

> word is support. How can the gifts that someone has support the kinds of initiatives that the community is interested in?" (p. 7, 00:33:41-00:34:22)

However, instead of collaborative problem defining and solving, existing systems may still incentivize the academic researcher entering a community to solve a problem, which is a systemic problem that in some local cases has roots in colonialism. Furthermore, academic systems tend to value quantifiable results like publications and future grants, which may be at odds with the needs of the community being engaged; within the academic system, this lack of quantifiable output can be problematic, as Summer noted: "So from a perspective of the university it's like, 'Oh, there was no output to this research.'" (p. 10)

Tara (Engineering)

Tara's interview transcript covered a large range of topics and included many specific examples related to problem defining and solving. Some of the specific problems she mentioned were related to students' thesis defenses and funding (p. 2, 00:08:28), the privilege of going to conferences (p. 3 00:13:19-00:13:49), a town with a contaminated quarry (p. 4, 00:16:23-00:16:34), assessment methods and equity of grades (p. 5, 00:17:42-00:18:33), and the "reference man" (p. 9, 00:42:54-00:00:44:36).

The most prevalent concepts that appeared in Tara's narrative were privilege and individualism. First, we highlight an example of "privilege" in Tara's interview. When asked to define macroethics and social justice, Tara briefly explained what each term meant to her, then told a story about not being able to attend a prestigious conference due to lack of privilege. This story was relevant to her overall point about lack of privilege contributing to social injustice, and she concluded that

> "When we talk about social justice, a lot of the time we forget that we are where we are not because how great we are, but because of the privileges we had, and there are people who are even better and smarter, more hardworking than us who had none of those privileges and could not get there." (p. 4, 00:15:22-00:15:47)

Tara's definitions and examples of social justice and macroethics provide a great example of a problem definition mindset in which Tara presented many elements and examined them in order to best solve a problem. She described herself as "going on a lot of tangents" (p. 5) in the interview transcript, which provided many examples to illustrate her point.

Related to problems in academic structures, Tara argued that "we need to change that system that we are doing these assessments in" (p. 4) because they are unfair to students with different needs, such as pregnant students and students with ADHD. These students were not those for whom the academic system was originally designed, leading to an identified problem of injustice. This discussion is another example of the "privilege" theme in Tara's interview.

Continuing on this theme in response to a subsequent interview question, Tara discussed structural and colonialistic aspects of academic social (in)justice.

> "it's a very hierarchical institution built on the colonial principles...but the work that is being done to change systems and policies, these are really things that will impact

> the system...But this critical review of all the policies and all the systems in place will help in a few years to change the systems. And then the culture will unfortunately take a lot longer to change, but system change helps culture changes a lot better." (p. 7)

As mentioned above, one of the two prevailing themes in Tara's interview was "individualism." Tara also suggested that colonialism may also be linked to a culture of individualism, in particular one in which people holding positions of less privilege and power and their interconnectedness may be invisible to those in power. Tara noted that people who hold individualistic mindsets might be less receptive to seeing problems related to social justice and macroethics.

> "sometimes the attitude of the people in [this city] is a lot more individualistic, but they don't understand the impact of the society on their life. So the privilege of living in a developed country, having your roads always working, your police not taking bribes, your systems always being in place, your infrastructure always being there, has made you not understand the impact of having people who can actually do these things in the future." (p. 8)

Individualism is also reflected in the culture Tara observed at the university. She mentioned that many times engineering students center themselves on the grades they are getting without seeing the utility of working in teams. She said "One of the biggest complaints we used to get is that, 'I am working with this group. I have no idea what this person's doing. They're bringing my marks down.'" (p. 11) In this example, individualism can certainly impact students' experiences in engineering education.

Discussion and Conclusions

Several common topics appeared across all of the interview transcripts that help to illustrate their mindsets related to problem solving. All four faculty described problems impacting their academic work. These descriptions suggest that all participants were practicing the first step of problem-solving, namely problem definition, within their positions. In particular, academic structures (often going beyond their own university) was a commonly-defined problem that hindered novelty and innovation in teaching and research. Further, their answers all reflected that they had put thought into their influence on students as educators and had a great interest in impacting the community in a positive manner using their respective disciplines, suggesting further steps in the problem-solving process. Perhaps inspired by the local context (see the "Context" subsection within "Methods"), all four specifically mentioned the need for decolonization or the inclusion of Indigenous narratives in academia.

In addition to this similar finding across interviews, we also considered the narratives of the Engineering (Leo and Tara) and Education (Lisa and Summer) faculty separately. Based on the literature and our own experiences we expected to find evidence of a problem-solving mindset in engineering, but were unsure how strongly it might appear from these faculty in education [9], [10]. As described in the Findings for each individual, we did see evidence of problem-solving mindsets in all four, which supported our expectations about the engineering faculty as well as giving new insights for education faculty. However, different qualities of the mindset appeared, as we summarize in this section.

Engineering Faculty Both Leo and Tara both brought up how doing transdisciplinary research can have negative impacts when working in academia. Tara suggested that the system has no established way to reward the process, which is a viewpoint consistent with Leo's interview. Both also note structural topics. Tara discussed how the system is built on colonial principles and Leo mentioned how junior faculty don't receive as much support for transdisciplinary research due to the academic structure.

Leo's interview was focused on the engineering perspective and how social justice could be incorporated into the largely technology-driven practice. Innovation was at the forefront of the conversation, specifically in regard to structures and standards that need to be changed. This engineering mindset was shown through frequent use of the words "problem," "solution," and "innovation." Leo also specifically defined and contextualized the terms "macroethics" and "social justice," which further demonstrated his problem-solving mindset, specifically the problem-defining stage.

Tara commonly used her personal experiences to incorporate many specific examples in her answers to each of the prompts. She demonstrated a problem defining mindset through her constant questioning and definition of established structures. Her focus in this interview circled around issues of privilege and individualism and as such she commonly mentioned the word "change," an example of active voice. Like Leo, Tara defined "social justice" and "macroethics;" however, Tara's responses included more detailed case studies, such as the ethics of concrete production that contaminates a nearby well to the point that the water is undrinkable. Tara tended to bring up more specific examples of personal lived experiences than Leo, who often related the content back to his work.

Both engineering faculty also mentioned the actions that they have taken while teaching to improve or compensate for the academic structure. Tara focused on ensuring that she accounted for differences in students' life paths and accommodated for them, as to not put non-traditional students at a disadvantage in comparison to their peers. She also attempted to combat the university's culture of individualism by having students work in a group. These two instances show that Tara's focus in improving the situations for students. Leo's interview, on the other hand, centered around helping society via innovation. One of his main actions is ensuring that students listen to stakeholders, "so that the societal buy-in at the end of the process is baked into the process rather than an afterthought" (00:05:47.520 - 00:07:00.060). His other actions also align with bettering society, like when he mentioned trying to incorporate an innovation mindset into the curriculum, in order to "train the leaders of tomorrow" (00:54:57.180 - 00:55:09.870).

Education Faculty Both Lisa and Summer expressed interest in fostering communal thinking and raising awareness to facilitate change. Lisa focused on how "change happens with awareness" (00:06:32.370 - 00:06:41.700) and Summer made similar comments. While both defined the value of discussing different issues in the educational setting, Summer emphasized that discussion must lead to action. Summer spoke frequently about decolonization in the broader community, while Lisa more often discussed EDI at the university. Both transcripts suggested ample time spent in the problem defining process.

Lisa's interview was concise and consistent in theme, specifically focused on equity and social justice. She mentioned both individual and structural aspects of EDI. Her problem-solving

mindset was evident in the desire to fix structural factors that negatively impact equity, inclusion, and justice, with evidence based in terms such as "fix," "making people be more aware," "trying to address," "empowering people," and "seeking to change." These are all examples of active voice, which Lisa maintained throughout the majority of her interview. Lisa also displayed a strength in problem definition, describing herself as "vigilant and constantly questioning" (00:13:09.930 - 00:13:27.600) structures and the impacts on those involved.

In contrast, Summer's interview provided numerous examples of problem definition, with comparatively fewer examples of direct problem solving. Summer posed many questions relevant to macroethics and social justice, demonstrating deep understanding and engagement of these topics in her work, including her teaching. She gave a number of examples of seeking to promote action in students and across the university to answer the questions and solve the problems she identified. While she did not demonstrate the same level of engagement with the problem-solving phase as Lisa, she described her teaching as a call to action and motivation for others to address the problems.

Disciplinary Contrasts. Although we emphasize that this small-*n* research is not generalizable to engineering and education as disciplines, we remark here on a key contrast in our analysis that could inspire future study: we noticed more extensive problem definition in education faculty's responses. While the engineering faculty often used problem definition as a vehicle to talk about their potential solutions, Summer and Lisa spent much more of their interviews exploring the problem definitions and how possible solutions would impact those involved. Leo's and Tara's relatively less time spent on problem definition could be suggestive of a mindset aligned with the step-by-step design process that is present in many engineering classes. There is often limited discussion regarding these steps, so much of the problem definition could be occurring internally for the engineering professors, not to mention being reduced to textbook word problems for the students. With the more discussion-based classes that are common in liberal arts educations, it follows that education professors might discuss each step of their problem solving process more openly and more extensively.

Implications for Engineering Education Many engineering professors strive to improve curriculum, student engagement, and their own teaching. While this is certainly not enough data to draw trends across disciplines, when looking at the narratives present across our participants we see less time spent in the problem-definition phase with the engineering professors compared to the education professors. We hypothesize that this different focus could result in different understandings of the qualities of the problems defined and thus likely different approaches to solving them. Awareness of different mindsets and transdisciplinary work can help to bridge these gaps. For example, in some cases there may be benefits to spending more time thoroughly understanding the problem before trying to apply a particular solution, while in others faster action toward solving the problem may be ideal.

Different perspectives provide insights into new avenues of thought. Examining knowledge and perspectives of engineering and education professors can help us reflect more deeply on the problem solving process. Such reflection has the potential to positively impact the way we teach engineering problem solving. This paper describes a variety of similarities and differences among the four transcripts, which we hope will inspire engineering educators to explore other viewpoints that can help them to improve engineering education.

Positionality

As with all research, our lived experiences have shaped our understanding of the data and therefore our findings. We are all affiliated with a science- and engineering-focused public university in the Western U.S. The first author is a combined Senior/Masters student studying Electrical Engineering and STEM Education who identifies as a White woman. The second author is a Hispanic undergraduate in Electrical Engineering. The third author is a Professor in an engineering department who identifies as a White woman and who conducts research in both a technical engineering discipline and in engineering education.

To protect the anonymity of our interviewees, we cannot detail most aspects of their demographics or their research areas beyond the information already provided in the Findings. We acknowledge that their demographics and detailed areas of expertise are likely relevant to their responses and suggest that future projects could seek to better understand such impacts.

Limitations

As with all research, this paper has limitations. Firstly, our team worked with a very small sample size due to the time needed to analyze each transcript's narrative, limiting the number of interviews we could include in the analysis. As is common in small-sample-size research, we are thus unable to make generalizations about our findings.

Further, Summer's and Tara's interviews were professionally transcribed, while Leo's and Lisa's were automatically transcribed via Zoom. The professional transcriptions were much easier to read and interpret than the Zoom transcriptions, which could have biased our interpretations.

Finally, as noted in the Positionality section, all three authors are from an engineering background. We attempted to mitigate our engineering biases by repeatedly questioning our conclusions, but realize it is impossible to compensate for these biases completely. Similarly, all three researchers — perhaps influenced by our identification as women in STEM — are passionate about improving EDI, which could have made us more receptive to some of the interviewee's responses. For example, EDI-related topics in academia were a major part of both Lisa's and Tara's interviews.

Future Work

In the future this research could be built upon by analyzing the remaining 14 interview transcripts from the original study, or by designing an entirely new study. In a new study, our research team would be interested in asking engineers and educators questions that specifically address problem-solving in their fields, as well as potentially expanding the range of professions included in the study. In a new study, we would request approval to share more demographic/positionality information about the interviewees, which could help strengthen their narratives and depth of the findings.

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Appendix: Interview Protocol

The semi-structured interviews were conducted by the third author according to the approved ethics procedure. The interview questions (with university name and city removed) were:

1. To help me get to know you, please tell me a little bit about your research and/or teaching interests and activities.
2. How do these interests and activities align with the broader vision for the University?
3. What do the terms "macroethics" and "social justice" mean to you?
4. Do macroethics and social justice play a role in your teaching or research, whether implicitly or explicitly? If so, please describe how.
5. Have you observed colleagues near your level of appointment supporting or encouraging
6. Have you observed university leaders (at any level) supporting or encouraging macroethics and/or social justice at the University? If so, please give some examples.
7. Tell me about how the local context (such as the province, city, etc.) in which the University is situated shapes your answers.
8. Are you connected (formally or informally) with people or communities whose voices you think might not be adequately heard in STEM education at the University or broader community?
   (a) If so, tell me what you have learned that suggests they have not been adequately heard without giving identifying information about any individuals.
   (b) If so, what do you think those of us in the STEM education community could or should do?
9. In addition to the University, do you work in K-12 and/or informal learning environments? If so, what similarities and differences do you observe between your University educational context and those in K-12 and/or informal learning environments?
10. (For interviewees in or with experience in Engineering) Do you observe any gaps between the engineering curricula (at University or more broadly in the province or Canada) and the engineering profession in which your students are likely to be employed? If so, please describe or give some examples.

11. (For interviewees who conduct research in engineering education) Describe the research methods do you use in your STEM education research. What do you find most useful? What do you think is most applicable to engineering education?
12. Are there any other questions you wish I had asked you during this interview?
13. Without threatening your anonymity, please describe any demographic information about yourself that you are comfortable sharing that may help me to understand your responses (e.g., gender, race, ethnicity, etc.). As with all of the questions, your response to this question is entirely voluntary.
14. I am using "snowball sampling" to find interview subjects for my research. Do you have any colleagues you would recommend me to contact?
15. Do you have any questions for me?

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