Why Would You Ask Me about Engineering Culture and Belonging? Introducing Social Science Prompts into Engineering Surveys

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Abstract:

What happens when researchers introduce socially theorized concepts like "culture" into engineering surveys as data generation prompts? While it is common for us to use social science theories to frame our analyses, it is less common for us to ask engineering students and practitioners to make sense of them through electronically administered surveys. In this paper, we examine 1198 open-ended responses to two items on a Canadian engineering career path survey: *Q65: What aspects of engineering culture make you feel like you belong?* and *Q66: What aspects of engineering culture cause you to question your belonging?* In addition to identifying specific factors that enhanced and constrained participants' sense of belonging in the profession, we observed three distinct ways of responding to our culture prompt: engage (14%), ignore (54%), and backlash (8%). When we disaggregated these findings by an intersectional gender/race category, we found that white men were over-represented in "backlash" responses (11%), racialized[1] men and women (76% RM, 71% RW) were over-represented in the "ignore" responses, and racialized and white women (23% RW, 20% WW) were over-represented in the "engage" responses. We use these findings to generate a justice-based argument for including social science prompts in engineering education research. Our position contrasts with positivist norms about minimizing response bias.[1-4] When we minimize the ambiguity of survey prompts, we adopt a standard set by the white, male majority, leaving dominant ideology intact. In contrast, when we integrate social science concepts into our survey, we provide an opening for the "subaltern" to speak.[5]

Introduction: Disrupting ideological hegemony in engineering by naming culture

Textbooks on survey design emphasize the importance of generating clearly worded, accessible prompts as a means of decreasing response bias,[1-4] but the concept of accessibility presumes a referent. For whom must our questions be clear? For whom may this demand for baseline clarity limit expression? Our primary argument in this paper is that the demand for accessible survey prompts may suppress what is utterable, or even thinkable in engineering education, resulting in an unacceptable erosion of analytic power for studies centering equity, diversity, and inclusion (EDI). Whose voices do we lose when we are restricted to normative discourse in our data collection instruments? Whose voices are raised in anger or disbelief when we nevertheless dare to invite participants to examine the water in which they swim? Our paper examines these issues by documenting what happened when we introduced the socially theorized concept "culture" in our national engineering career path survey:

> *"I'm not sure what you mean about engineering culture. To me it is a culture of checking and rechecking and making sure things are right. That isn't making me question my belonging in engineering."*

Without follow up questions, we cannot be sure if this individual was asking a genuine clarification question or criticizing our survey protocol, but on our end, we should point out that we did not intend to anger respondents. We actually included this question for the opposite reason, to avoid presuming we knew what they were thinking. As a team of engineering educators made up of critical and social constructivist researchers, we often use social theories to make sense of participants' narratives after the data collection process is complete. In this case, we wished to invite Canadian engineers to become involved in the sense-making process by asking them directly about the relationship between engineering culture and their career journeys. While some answered the question, the majority either ignored the "culture" part of the prompt or explicitly lashed out at our use of the term. Our paper combines a content analysis of their responses with a critical analysis of three distinct response types—

[1] The term "racialized" is often used in Canada to counter the white supremacist assumption that white people are without race. That is, people who do not benefit from white privilege are "racialized" by society. It is not that they have a race and others do not, but rather that racist norms in Canadian society treat people with black and brown skin in this way. We understand that different terminology is used in the United States.

engage, ignore, and backlash. Before jumping into the analysis, however, we clarify what we mean by "culture" drawing on two disciplines, cultural studies (Hall)[6-8] and organizational studies (Schein).[9] We then review the engineering education literature for explicit and implicit references to professional culture to see how the idea is taken up in our field. Stuart Hall, one of the key founders of cultural studies in the UK, characterizes culture in semiotic terms:

> *Culture is concerned with the production and exchange of meanings…between members of a society or group. To say that two people belong to the same culture is to say that they interpret the world in roughly the same ways and can express themselves, their thoughts, and feelings about the world, in ways which would be understood by each other. Thus, culture depends on its participants interpreting meaningfully what is happening around them, and "making sense" of the world, in broadly similar ways. (p.2)*[7]

For Hall, this communal sense making project is deeply contextualized, and has the "tendency to take on the intellectual coloration of the place where it is operating." (p.24)[8] He characterizes culture as indivisible from power and underlines the "historic inertia"[8] of dominant narratives. Hall theorizes the idea of shared culture in socially constructed ways, as meaning regularly being made, remade, and expressed through political struggle that "imposes particular maps on our understanding"[8] (p.30). Drawing on Gramsci's notion of "cultural hegemony,"[10] Hall characterizes dominant narratives as difficult to disrupt, but sufficiently dynamic to create space for reframing and resistance. Applying Hall's understanding of culture to a Canadian engineering ritual, recent engineering graduates may understand the dominant narrative shared with them during the Ritual Calling of the Engineer, but the sense they make of this historically durable message will differ, sometimes imperceptibly along the communication path from encoding to decoding.[11, 12] With every story experienced, interpreted, and passed on, the meaning of the ritual is subtly changed, while also being reinforced.

Like Hall, Schein invokes the notion of context and power in his definition of culture but he does so through the discipline of organizational studies rather than communications.[9] For Schein, culture is:

> *"a pattern of shared basic assumptions learned by a group as it solved it's problems of external adaptation and internal integration, which has worked well enough to be considered valid and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems." (p.18)*

Schein departs from Hall in his foregrounding of socialization over expression, but both theorists characterize culture as a socially constructed phenomenon generated in context through struggle and ossified over time. For Schein, organizational culture is formalized when it is passed down to and received by the next generation of insiders. Schein's three level model of culture is relatively easy to apply to a wide range of disciplines because it is not specifically bound in space or time. The three levels of culture in his model include "artifacts, espoused values, and basic underlying assumptions" (p.24). At the risk of oversimplifying his model, *artifacts* are observable structures, processes, and behaviours; *espoused values* are explicitly named ideals, goals, and aspirations, and *basic underlying assumptions* are taken for granted beliefs that are largely unconscious for insiders. Returning to the Ritual Calling of the Engineer—one of the most powerful *artifacts* in Canadian engineering culture is an iron (or stainless steel) ring conferred upon graduating engineering students by their predecessors in a private ceremony. The observable behaviours, processes, rules, and rituals that make up the ceremony are also artifacts. The next level, *espoused values,* are more abstract but still explicitly communicated to insiders. For example, one of the key espoused values attached to the ring is the ethical obligation to protect society, rooted in the Quebec bridge collapse of 1907. Those who attend this ceremony are impressed upon to

accept their obligation to society as ethical professionals who have taken an oath to protect the public. The *basic underlying assumption* of this espoused value is difficult to accurately decipher, but between material artefacts like the ring and chains, and linguistic artefacts, like reference to their "betters," it seems to rest on a brotherhood of applied scientists bound by the duty to fight against technical failure from a societally subordinate position. For a carefully constructed analysis of this ritual, see Paul et al's recently published article, "Stubborn boundaries: the iron ring ritual as a case of mapping, resisting, and transforming Canadian engineering ethics."[12] One strategy used by Schein to reveal otherwise masked underlying assumptions is to compare the "espoused" and "enacted" values of a group. By comparing what insiders profess to care about (public welfare), with the values implied by the everyday actions of the majority (technical problem solving), it is possible to unearth the operating principles and underlying beliefs of a culture (professional responsibility for technical failures). Fortunately, while the culture of any profession is powerful, it is rarely static. Recently, a group of Canadian engineering graduates has begun resisting exclusionary (sexist, racist, colonial) elements fortified by the ritual, while retaining the espoused value of public welfare.[11, 12] In their own words, this group of engineers is "retooling" (not rejecting) the ring. Schein's operationalization of culture through this three-level model can help us explain the powerful, but unstated barriers faced by those who uphold the espoused values of the engineering profession while raising questions about enacted practices that contradict or contract the ideal. Schein's model was partly based on his research in engineering intensive organizations, but his work is not classified as engineering education research. We now turn our attention to the growing body of engineering education literature that takes professional culture as its central phenomenon.

Anybody who has witnessed a sea of purple bodies singing about lady Godiva in early September, or small cars perched improbably, yet stably on top of campus buildings may guess that engineering has an observable culture. Where did this idea of engineering culture from? In his study of cultures in higher education, Grondin characterizes engineering as one of four liberal education "cultures."[13] He bases his argument on, Kagan's book, *The three Cultures: Natural Sciences, Social sciences, and the Humanities in the 21st century*.[14] Grondin takes issue with Kagan's omission of engineering as a liberal education culture. While Kagan includes engineering in his text, he characterizes it as an application of science. Grondin disputes this supplementary characterization by arguing that engineering is uniquely concerned with the "creation, development, and deployment of material entities imbued with utilitarian intentionality." (p.12) Engineering, according to Grondin, is a discrete culture because it has distinct sources of evidence, vocabulary, and criteria for beauty that minimally overlap with Kagan's three existing "cultures." By differentiating engineering from the natural sciences, Grondin secures a foundational place for it in the history of liberal education, but he does so at the expense of internal disciplinary diversity, producing a monolithic, utilitarian view of engineering culture.

Godfrey and Parkers' regularly cited ethnographic study of an engineering school in New Zealand fleshes out this monolithic culture in a particular institutional context.[15] Drawing on Schein's model, they identify six dimensions of engineering culture: 1) an engineering way of thinking tied to tangible, measurable, quantifiable realities, 2) an engineering way of doing characterized as "hard," 3) an engineering way of being involving a "can do" attitude prioritizing effective and efficient problem solving, 4) a growing acceptance of difference linked to increasing demographic, disciplinary, and experiential diversity in the school, 5) a relational commitment to study teams as a survival tactic, and 6) a mentality of "going it alone" as a faculty, separating their institutional identity from the rest of the university.[15] Among the many engineering education researchers who have cited Godfrey and Parker's study, Deters and Paretti investigate the extent to which their six dimensions of engineering culture hold up under crisis, using the disruptive period of the Covid-19 pandemic as the crisis. The authors set out to explore the stagnation of DEI efforts during times of strain and found that Godfrey and Parker's findings held up well enough to be meaningfully used as a framework.[16] The fact that six dimensions of

engineering culture drawn from an ethnographic study conducted in New Zealand remained salient many years later in a US-based engineering department, during a period of global crisis, suggests that there is something structurally persistent about engineering culture across national contexts. Miller, Cross, and Jenson similarly draw on Godfrey and Parker's framework to help them frame a DEI project. In particular, they identify the consequences of harsh cultural norms on undergraduate students' mental health, with a specific focus on underrepresented communities.[17] The authors surveyed undergraduate engineering students at a large public institution in the United States and found that perceptions of inclusion, mental health, and engineering identity differed across programs, with significantly lower diversity rankings in male dominated departments. They concluded that engineering departments have distinct cultures and the capacity to influence student perceptions about inclusion.[17] The authoritative power of these departments, suggests that engineering culture can shift if programs, schools, and departments actually enact the university's espoused DEI values.

Contrasting with the primarily descriptive approach taken by researchers cited above, Bates and her colleagues invoke Schein's model of culture in a more agentic manner. Their paper documents the development of two new project-based engineering programs seeking accreditation.[18] Their intention to "build a more inclusive culture for tomorrow's engineers" differs from Godfrey and Parker's use of culture as a vehicle for ethnographic insight about an existing institutional context.[18] Bates et al.'s call for change urges us to view engineering culture as malleable. Along the same vein, Tonso,[19] Riley,[20] Kim et al,[21, 22] Patrick et al,[23] and Johnson[24] propose cultural change strategies for engineering educators and practitioners. Tonso calls for cultural change in engineering education based on feminist critique rather than "cosmetic changes,"[19] Riley urges us to strengthen cultures of accountability and fidelity to core public and professional values in the wake of high profile engineering scandals,[20] Kim and her colleagues call for shifts in engineers' moral formation to foster ethical practice in industry, [22, 25-27] Patrick and her colleagues advocate for educational reform to replace technical silos with interdisciplinary collaboration between engineers and STS (science and technology studies) scholars,[23] and Johnson urges us to grapple with the inherent tension between growth-oriented mining culture and the relational stewardship culture passed down to many Indigenous peoples faced with the extraction of mineral deposits on their traditional territories.[24] These ten studies have different foci and take place in different contexts but they are connected by authors' explicit use of "engineering culture" as a structural barrier to ethical and/or equitable practice in the profession.

Finally, a powerful group of critical engineering studies scholars have set out to disrupt normative engineering culture without necessarily using the term "culture" as a keyword. Instead, they have identified dominant mindsets,[28] ideologies,[29-34] and frameworks,[35-37] that provide us with a window into engineering education and practice. We review a small number of their foundational works here. Riley's chapter on engineering mindsets uses engineering jokes to draw out normative perspectives rooted in stereotypes.[28] Each joke reveals an underlying assumption about what it means to be a "real" engineer—adoption of a positivist epistemology, acceptance of military authority, elevation of technical certainty over subjective interpretation, disdain for literacy, and a single-minded focus on technical optimization. She points out that while self-deprecating jokes may lighten the mood, they can also be used to deflect attention from these otherwise serious and consequential commitments, erecting an obstacle to socially just change. Her argument affirms Godfrey and Parker's finding that "being an engineer" involves prioritizing light-hearted teasing over intensive engagement with conflict, which is itself a defence against critical thought. Along similar lines, Cech identifies two dominant ideologies in engineering culture that hinder engineers' ability to acknowledge social injustice—depoliticization and meritocracy.[33] Picking up on the notion of merit, Stevens et al. analyzed engineering students' narratives about why they wished to become professional engineers and found a persistent "meritocracy of difficulty" belief paired with justifications for a comfortable engineering lifestyle.[38, 39] These empirical

findings have deep historical roots. In an historical account of social responsibility in the engineering profession, Layton traced the durability of business and science as authority structures in engineers' professional practice.[40] To draw out the connection we are making between Cech's, Steven's and Layton's work, American business is rooted in the idea of free market capitalism which builds on the underlying assumption that those with smarts and grit will advance (meritocracy), while science is rooted in a commitment to objectivity which is itself based on the underlying assumption of depoliticized inquiry. Together, these three studies conducted from different disciplinary perspectives suggest that meritocracy and depoliticization are deeply embedded features of engineering culture and thus cannot be easily dislodged. Adding to these ideologies, Smith shares an intense commitment to pragmatism constraining mining engineers' engagement in social critique and activism,[41] Secules' characterizes engineering education culture as masculine and competitive,[42] Tonso's calls our attention to violent masculinities as tropes for school shooters,[43] Faulkner contrasts "nuts and bolts" identities with socio-technical realities in five engineering intensive organizations,[29-32] Holly, Cross, and Lee reveal the white default in engineering education which inhibits accountability for racial injustice, and Secules, Meija, and Chen critique anaemic DEI initiatives.[36, 44-53] In all cases, authors draw attention to seemingly benign aspects of engineering culture that thwart social justice efforts.

Naming dominant ideologies embedded in engineering culture can be destabilizing for engineers who are advantaged by hegemonic norms, and dangerous for engineers who are disadvantaged by them. As critical engineering educators and researchers, we nevertheless continue to name, study, and teach about engineering culture because of the liberatory potential of separating espoused and enacted values. Unfortunately, the research on engineering culture tends to focus on undergraduate classrooms, remaining at some distance from professional practice. Our paper builds on the body of literature reviewed above by examining what happens when we bring the worlds of social science theory and engineering practice together through a socially theorized survey prompt. In particular, we ask the following research questions:

- RQ1: How does engineering culture enhance and constrain Canadian engineers' sense of professional belonging?
- RQ2: What kinds of data do we get from whom when we use the social construct "engineering culture" as an explicit survey prompt?
- RQ3: How can we use these findings for liberatory ends without further alienating marginalized engineering communities?

Methods: Critical analysis of open-ended items on a cross-Canada Survey

The lines of analysis we present in this paper are part of a larger study on engineering career paths and EDI (equity, diversity, and inclusion), which was itself a follow up study to a project examining engineering leadership development in professional practice contexts.[50, 54] For the initial qualitative project we used career history interviews[55-57] with 29 senior engineers in eight industries to understand how engineers learn to lead. We used the career history method to aid recall since most of the engineers in our earlier studies struggled to answer direct questions about leadership. In the end, we found that participants' leadership development opportunities differed by career path, and that access to the paths differed by demographics in ways that reflected broader ruling relations in western societies.[50, 58] Given the power of participants' career trajectories in their leadership development narratives we decided to conduct a larger, national study on engineering career paths and EDI.

The primary purpose of this follow-up study was to learn about the relationship between engineering career paths and equity on a larger scale. After securing a small federal grant from the Social Sciences and Humanities Research Council of Canada (SSHRC), and undergoing institutional ethical review, we drafted a survey protocol to test the five emergent career paths from our earlier study. We shared the

draft with industry partners, colleagues at Engineers' Canada, and members of EDI groups on campus for feedback, then translated the protocol into French. In November 2022, we launched the survey with the support of Engineers Canada, seven provincial and two territorial professional engineering associations, the engineering alumni office at two Canadian universities, Engineering Deans Canada, and two equity-oriented societies on campus (WISE and NSBE). We left the survey open for one month. 982 engineering degree holders completed the survey. We had two delimiting factors: participants had to have completed their undergraduate engineering degrees at least 10 years prior to our survey launch and they had to either have completed their engineering training in Canada or be working in Canada. Please see Table 1 for information about our sample.

Table 1: Survey Sample

Variable	% of Sample (n=982)
Licensed PEng	87%
Location of training	86% domestic, 11% internationally educated
Age category	34% (30-45 y); 47% (46-65y); 17% (66+)
Gender	25% cis women, 74% cis men, 0.3% non-binary/trans
Race	82%White, 13% Racially Minoritized (4% East Asian, 3% South Asian, 2% Black, 1% Indigenous/FN/Metis)
Race x Gender category	66% white men, 21% white women, 9% racialized men, 5% racialized women
Sexual Orientation	90.4% heterosexual, 2.6% LGBTQ+
U/G major	30% civil, 22% mechanical, 14% electrical, 11% chemical, 6% mining/geological
Industry	23% prof services, 17% mining/oil& gas, 11% manufacturing, 10% construction, 8% power/utilities, 8% infrastructure, 7% govt/public admin
Sector	73% private, 17% public, 9% para-public (hospitals, universities, utilities)
Workplace location	73% urban, 13% suburban, 9% rural, 5% remote (far north/overseas)
Organization size	9% consultant, 6% micro, 8% small (10-49), 15% medium (50-249), 61% large (250+)
Province/Territory	42% ON, 19% NL, 9% AB, 7%BC, 7% NWT/NU/YK, 4% NS

Our delimiting factors resulted in a predictable over-representation of older, licensed engineers, but our gender breakdown reflected that of licenced engineers in Canada. With respect to race, we lack the national data necessary to compare our sample to the population of Canadian engineering graduates. In terms of regional breakdowns, differential recruitment strategies used by professional regulatory bodies (mailing lists vs social media blasts) influenced participation rates. The small number of respondents from Manitoba, Saskatchewan, and Quebec reflect the fact that regulators in these three provinces did not disseminate our survey. Relatively high numbers in Newfoundland/Labrador, Northwest Territories/ Nunavut, and Yukon Territory reflect the active dissemination efforts of regulators who sent our survey to their full membership through mailing lists. High numbers in Ontario reflect the strong distribution efforts of our provincial engineering advocacy body and university-based alumni network. Low response rates in the Atlantic provinces (other than Newfoundland and Labrador) were the product of a storm that took out the electrical grid around the time of our launch.

The survey was much longer than those we typically use in university contexts. It had 69 questions broken into 5 sections: professional background (3-13), demographics (14-21), career path (22-38), career advancement (39-59), and professional belonging/identity (60-67). The typical time to completion was 15-20 minutes. Between 578 and 982 survey respondents completed each question. Interestingly, despite the length of the survey, we did not notice a clear drop off from beginning to end, but open-ended, demographic, and EDI-related questions had lower response rates than forced choice or minimally invasive questions. Open-ended questions had between 578 and 891 completed responses. Our analysis for this paper focuses on two open-ended questions located near the end of the survey:

- *Q65: What aspects of engineering culture make you feel like you belong? (n=598)*
- *Q66: What aspects of engineering culture cause you to question your belonging? (n=578)*

Given the focus on belonging, we also share responses to a related quantitative question analyzed in a previous paper (Q62).[59]

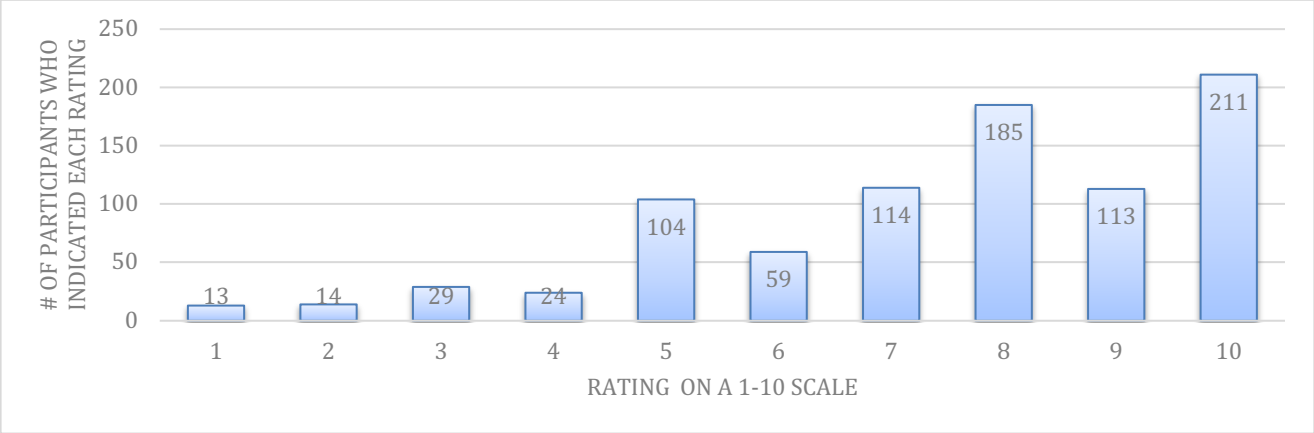
- *Q62: On a scale of 1-10, please rate your sense of belonging in the engineering profession. (N=913)*

We analyzed all three questions for the full sample then disaggregated our findings by an intersectional gender/race variable, following Crenshaw's argument that justice for racialized women requires us to go beyond main effects on gender and race.[60] Other than the response rate for Q65 which was greater among racialized participants than white participants, other questions had roughly similar response rates across demographic groups. We use a combination of descriptive (frequencies and means) and inferential (Chi Square) statistics for the quantitative question and a combination of thematic and critical analysis for the two qualitative questions.[61, 62] We transformed themes into numeric codes and assigned relevant codes to all 1198 open-ended responses. We did this to illustrate thematic patterns in the full dataset rather than to make statistical comparisons between groups. We then disaggregated the codes by our gender/race variable. After noting that very few participants actively engaged with the "culture" prompt, we collapsed thematic groupings into three categories—engage, ignore, and backlash.

Findings:
Of the four intersectional gender/race groups, racialized women experienced the lowest levels of belonging, but highest levels of engagement with our explicit "culture" prompt. We explore these findings below, organized by survey question.

Q62: Racialized women experience slightly lower levels of belonging than the other three groups
When we invited participants to rate their sense of belonging on a scale of 1 to 10, with 1 labeled "I do not feel like I belong," 5 labeled "I feel some sense of belonging," and 10 labeled "I feel a very strong sense of belonging," the mean rating was 7.5, suggesting that on the whole engineers feel like they belong. Interestingly, the mode on this question corresponded with a rating of 10 indicating that a critical mass of participants experienced a very strong sense of belonging. Please see figure 1 for a distribution of belonging ratings for the full sample.

Figure 1: Q62 Rate your belonging (full sample) (n=933)

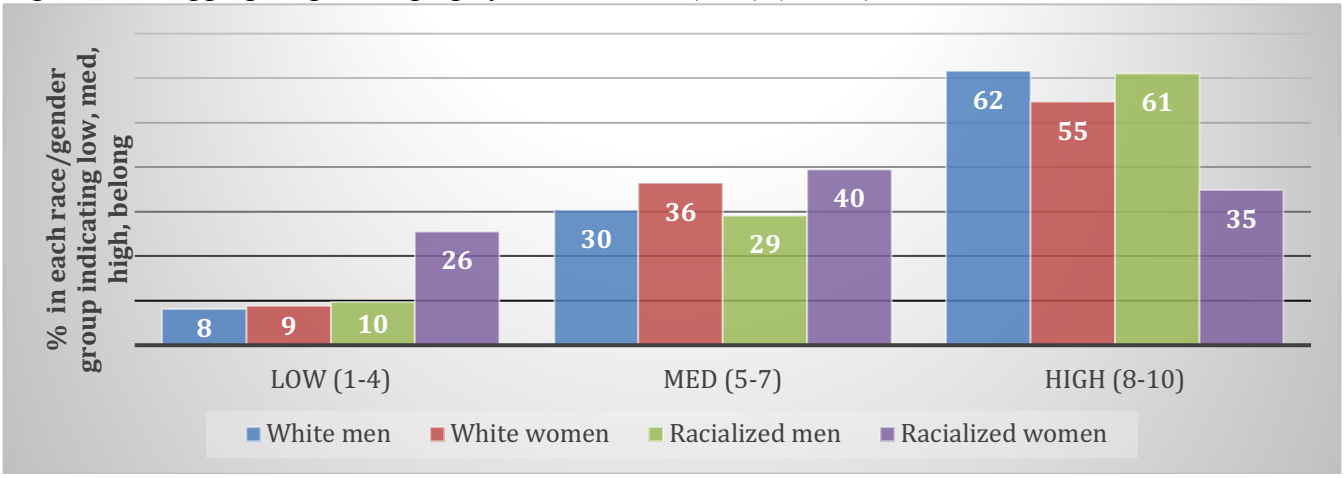


We disaggregated the findings by our intersectional race/gender variable, grouping participants' ratings into low (1-4), medium (5-7), and high (8-10) belonging and found that racialized[2] women were over-

[2] The term "racialized" is often used in Canada to counter the white supremacist assumption that white people are without race. That is, people who do not benefit from white privilege are "racialized" by society. It is not that they

represented among those who rated their belonging as low, and under-represented among those who rated their belonging as high. The other three race/gender groups had roughly even ratings. Please see figure 2 for an illustration of this finding.

Figure 2: Disaggregating Belonging by Gender/Race (Q62) (n=933)



In an earlier analysis,[59] Radebe et al. separated the findings into two rather than three belonging categories (low 1-7; high 8-10) and found that gender had a significant impact on participants' sense of belonging with 50% of women and 39% of men indicating a lower sense of belonging (N=910, χ^2 = 8.731, df=1, $\rho < 0.01$). There was no similarly significant main effect for race, but when disaggregated by our gender/race category, we found significant between-group differences suggesting significantly lower sense of belonging among racialized women than the other three groups (N=866, χ^2 = 13.384, df=3, $\rho < 0.01$).[59] Radebe et al. conducted a critical content analysis of open-ended responses completed by racialized women in response to Q63: "explain your rating" and found that racialized women with a lower sense of belonging (1-7) explained their ratings in three distinct ways: limited visibility tied to under-representation in the workplace, discrimination, barriers to licensure, and movement into non-technical jobs, while racialized women indicating a higher sense of belonging (8-10) explained their ratings by sharing their overall comfort with their racial and gender identities irrespective of systemic barriers.[59] Our current analysis extends these findings by analyzing responses to two follow up open-ended questions invoking the idea of engineering culture as a possible explanation for enhanced and constrained belonging. While some participants viewed the questions as unnecessarily repetitive, others took up our invitation to discuss their belonging in terms of engineering culture.

Q65: Technical mindset, comradery, and recognition enhance engineers' sense of belonging

Of the 69 questions we asked participants in our survey, two prompted them to examine engineering culture. Question 65 asked them to reflect on the aspects of engineering culture that made them feel like they belonged. Our thematic analysis of 610 open-ended responses to this question resulted in 22 codes which we grouped into five larger categories. Please see figure 3 for a list of categories and codes. After identifying these themes, we returned to the 610 responses and coded them, transforming qualitative themes into quantitative codes. We then disaggregated the findings by race/gender. Please see figure 4 for a stacked bar chart illustrating these findings. Numbers represent the percentage of individuals in each race/gender group who responded in each way. We are not conducting statistical analyses on these findings because they began as qualitative data.

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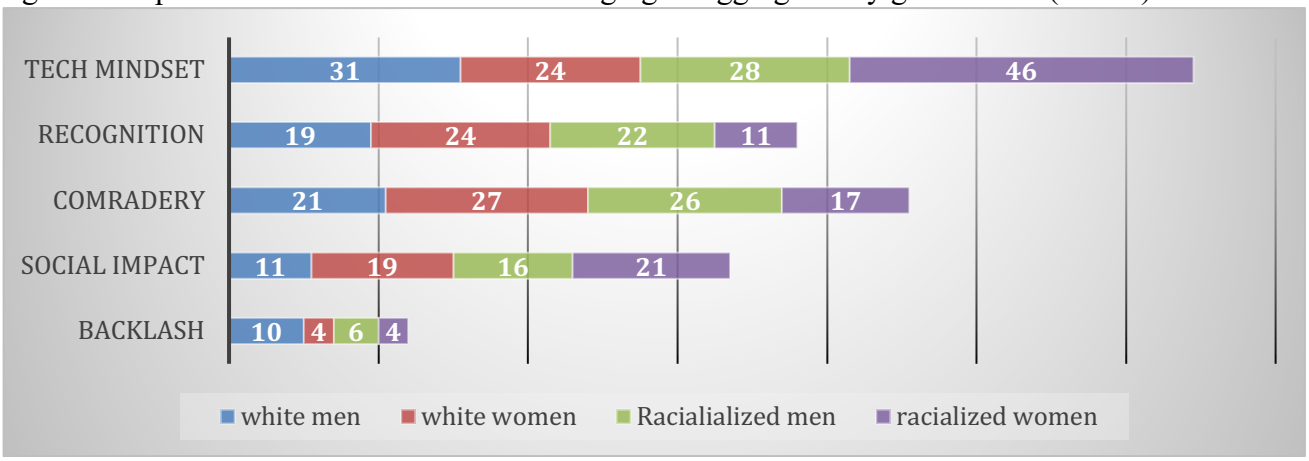
have a race and others do not, but rather that racist norms in Canadian society treat people with black and brown skin in this way.

Figure 3: Q65—Aspects of engineering culture that enhance belonging (n=610)

1) **Shared technical training & engineering mindset make it easier to communicate**
   a. Shared engineering mindset/attitude/values/traits
   b. Communication is easier since we speak the same language
   c. Technical > emotional/political; Technical/evidence-based/rational
   d. Shared training, knowledge, skills, experience legitimize insider status
   e. Motivated by technical culture of excellence/innovation
2) **Recognition of my competence affirms my belonging**
   a. Competent at/pride in/enjoy the work engineers get to do (internal)
   b. I am sought out/respected/trusted/listened to by others (external recognition of competence)
   c. Applying engineering skills in professional practice to the full lifecycle of a project
3) **Teamwork, comradery, and professional affiliation enhance my belonging**
   a. Collaboratively solving complex problems as a member of a team
   b. Leading, managing, mentoring others makes me feel like I belong
   c. Comradery; fraternal respect for others in the profession
   d. Strong professional organizations facilitate belonging—(involvement in professional, university, industry, and other networks)
4) **Engineers' contributions to society inspire/make space for me**
   a. Engineers' professional ethical dedication to making a better world inspire me
   b. Improved representation, EDI, and localized community impact make space for me/inspire me
   c. Engineers safeguard environmentalism & sustainability; health & safety through our work
   d. We are great at optimizing business solutions and enhancing the economy
   e. It feels rewarding to see your work materialize: building products that work
5) **Culture and belonging?**
   a. Not sure what about culture works for me, but I belong (all of it)
   b. Resistance to the question (culture or belonging)
   c. Nothing about engineering culture enhances my belonging (none)
   d. I don't know
   e. I refuse to accept cultural norms—and will assert my belonging because it's the right way forward

As illustrated in figure 4, the top three categories for the full sample were a shared technical mindset, comradery, and recognition—with white men and racialized women over-represented among those who viewed a shared technical mindset as enhancing their belonging, white women and racialized men over-represented among those who viewed recognition and comradery as enhancing their belonging, racialized women over-represented among those who viewed social impact as enhancing their belonging, and white men over-represented among those who expressed opposition to the question.

Figure 4: Aspects of culture that enhance belonging disaggregated by gender/race (n=610)



Looking at the five larger categories helped us generate a readable graph, but it masked the more subtle ways in which engineers in the four gender/race groups fleshed out the themes. Please see table 2 below for prevalent sub-codes and illustrative quotations emerging from each group.

Table 2: Illustrative quotations of the most prevalent code by gender/race category (n=610)

Gender/Race Cat	Most prevalent Code	Aspects of engineering culture that enhance your belonging
White men	3a: Solving complex problems as a member of a team	"*We have a large team of engineers at work who help and support each other. Having complex demanding projects gives us a common purpose and helps to bring us together."*
White women	2a Competent & enjoy the work engineers do	*"I am a good problem solver and enjoy the challenge of making strategic assessments and decisions. These skills are valued in engineering."*
Racialized men	2c Applying engineering skills to the full lifecycle of a project	*"Commissioning a project and the fanfare that follows, the conceptual design phase and the arguments that ensue, the design-development and test phases and the need to revise, improve, correct, the resulting documentation and reports - just about every corner of engineering work."*
Racialized women	1a Engineering mindset	*"I have a problem-solving mindset. Being a curious and innovative person, who likes to solve problems with an emphasis on logic, based in science."*

Interestingly, despite our explicit prompt to discuss engineering culture, very few participants framed their responses in cultural terms. Instead, they spoke about the engineering-intensive work they did that brought them career satisfaction. The prominence of technical affinity in the responses of racialized women was also noteworthy. This finding challenges the implicit, and somewhat essentialist assumptions about women in general, and racialized women in particular, underlying recruitment and retention efforts that magnify the socio-emotional features of engineers' work in order to diversify the profession. Racialized women, just like their peers, tended to speak about "nerd culture" and technical problem solving as features of engineering work that enhanced their belonging. Eliminating racism and sexism from their day-to-day work would likely be more impactful than sending messages about the social dimensions of engineering to secondary school students. To be sure, participants across all demographic groups cited social impact as an important feature of their work, and women (both racialized and white) were over-represented in the social impact category, but it was not the primary aspect enhancing their sense of belonging. Returning to the notion of culture, the few participants who explicitly mentioned engineering culture in their responses to Q65 discussed the ease of communicating with other engineers who spoke the same language, "I find that interacting with fellow engineers is far easier than other non-technical people. My brain doesn't have to work as hard to communicate on a level they understand." We return to this point in our discussion.

Q66: Converting social science prompts to "plain" language makes questions easier to answer

We used the same analytic process with Q66 as we did with Q65. We began coding the full sample of open-ended responses using an inductive, thematic coding process, organized the resulting codes into larger themes, then returned to the 588 open-ended responses with the final list of themes and codes. We then disaggregated the codes using our gender/race variable. As we engaged in this process, we noticed that very few participants engaged explicitly with the idea of engineering culture. Most either skipped over or reframed our use of the word "culture" in their explanation of factors that constrained their belonging. Some pointed out that nothing caused them to question their belonging, others spoke about the poor behaviour of some engineers, and many others located the problem outside of engineering entirely. From the relatively small group of respondents who directly engaged with our culture prompt, we heard stories of an old boys club, technical singlemindedness, an ERTW (engineers rule the world) mentality, and alcohol infused hard work/hard play[63] culture. All four of these cultural tropes reflect

previously cited research on dominant ideologies in engineering.[28, 29, 33, 39, 42, 63-65] Finally, a small but vocal minority of survey respondents expressed opposition to our use of the word "culture." Before diving into these results, we share our initial thematic analysis of question 66 in figure 5.

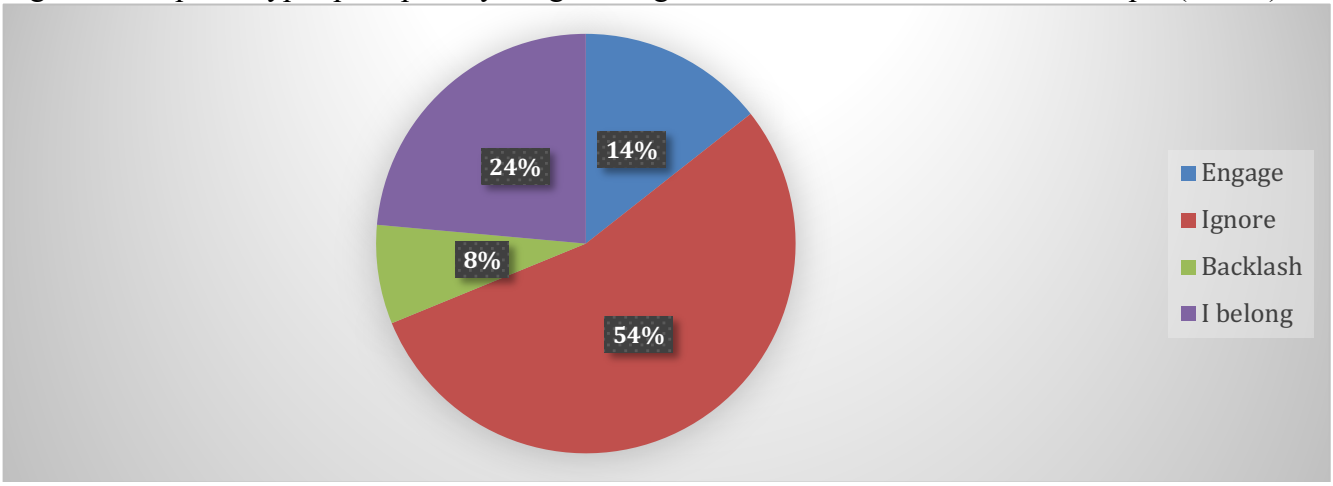
Figure 5: Q66—Aspects of engineering culture that constrain belonging (n=588)

1) **Dominant ideologies within engineering culture erode my belonging**
    a. Masculine old boys club culture, racist, sexist, homophobic brotherhood
    b. Technical arrogance/singlemindedness, micro-optimize details that don't matter
    c. ERTW (engineers rule the world) (presumed superiority, false pride, other at fault—inflated egos)
    d. Hard work/hard play culture
2) **There are problems within engineering, but mostly rooted in the poor behaviour of individuals**
    a. Discrimination (gender, race, sexuality, accent), tech credibility challenged (but not naming culture)
    b. Lack of diversity, underrepresentation, especially wrt advancement in senior management
    c. Disciplinary/industry silos/hierarchies—some disciplines/work considered "real" engineering
    d. Cliquey social scene, everybody has the same values, lack of social skills/rigidity (bar, men, sports)
    e. Conformity, risk-averse behaviour constrains creativity, rigidity of thought
    f. Some engineers bad at their jobs/low quality standards
    g. Role based hierarchies, "real engineering" does not include those of us outside of tech/design roles
    h. Technical nitpickiness of some engineers/ technically narrow solutions, exclusive tech focus
    i. Engineers who don't care about or consider social impact or the environment
3) ***I* just don't fit in**
    a. Lack of confidence in competence—imposter syndrome
    b. Different workstyles/ personality than the typical engineer
    c. Steadily losing Interest/satisfaction in engineering is waning, time for a career change
4) **Macro level external forces are the problem (not engineering)—society doesn't get us!**
    a. Lack of respect, undervaluing, underappreciating, or misunderstanding engineers' work/importance
    b. Politicization of engineers' work (ignoring sound tech advice), internal politics
    c. Economic bottom line results in low tech quality standards, corruption, erosion of ethical judgement
    d. The problems exist in society, engineering is just a microcosm of that
5) **Meso level external forces are ethe problem (not engineering)—stop controlling me!**
    a. Prof society doesn't represent me, regulate engineers' work/gatekeepers OR protective guilds
    b. Employers, managerial/bureaucratic control, non tech PM making decisions
    c. Accountability/liability falls to engineers who lack decision-making authority
    d. Unfair or limited mobility/advancement (gendered/raced)
    e. Limited supports (mentorship, sponsorship, role models, networks, mat leave and return)
    f. Limited work/life balance—intensification of work, dedication equated with long hours
    g. The job isn't technical enough
6) **Nothing causes me to question my belonging in engineering**
    a. I can't think of any, don't know, not sure
    b. N/A, nothing, none, aucun, nil, no issues here
    c. I belong, I don't question my belonging to anything
7) **Backlash—resent the implication that engineering culture is the problem**
    a. What do you mean by culture? Define it. I don't understand the question.
    b. Resisting the premise of the question, often in ALL CAPS
    c. Recalling the golden days of "merit" based advancement and high technical standards
    d. Woke EDI culture is the problem!

When we examined the 34 codes and seven themes for insights on engineering culture, we found that only 14% of participants engaged directly with our prompt, describing how engineering culture constrained their sense of belonging (1a-d). An additional 24% suggested that nothing constrained their belonging (6a-c). The majority of participants (54%) ignored the word culture entirely, answering the questions as though we had asked what factors constrained their work (2a-5g). While this group named a wide range of distinct barriers, they all skipped over or reframed our "culture" question. Participants used this open-ended response box to describe the poor behaviour of some engineers, society's disrespect for the engineering profession, and meso-level forces that controlled them a work. Finally, a

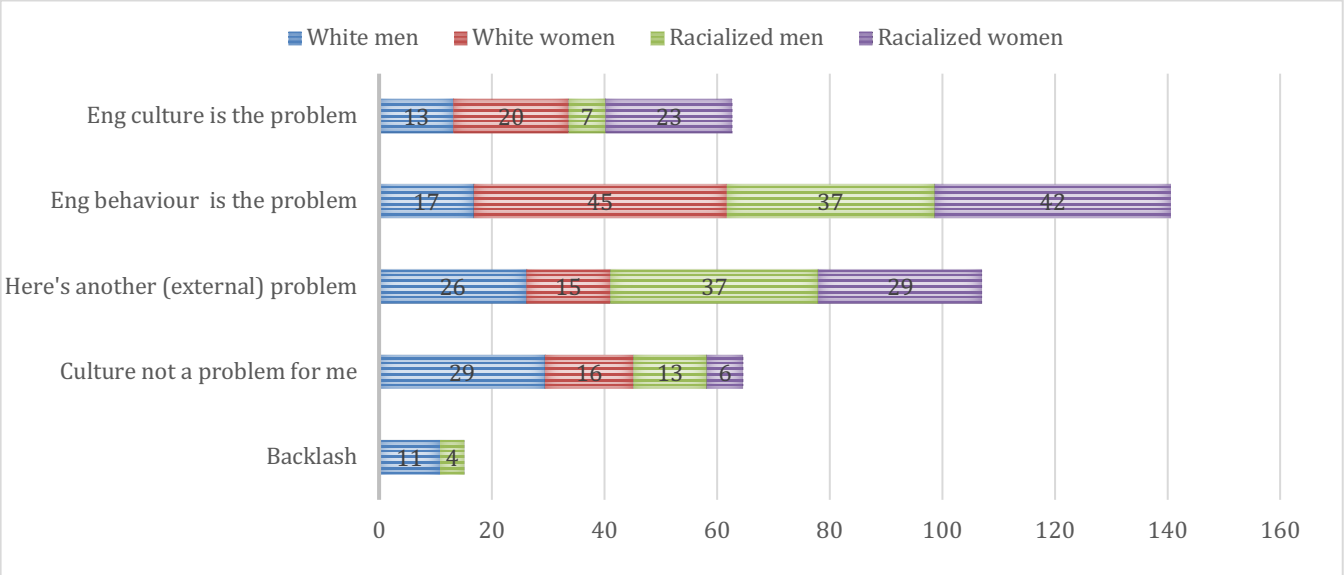
smaller, but somewhat longwinded subgroup (8%) expressed opposition to our use of the word "culture." Please see figure 6 for an illustration of response types across the full sample.

Figure 6: Response types prompted by "engineering culture" as a constraint for full sample (n=588)



We disaggregated these findings by our intersectional gender/race category and found that white men were over-represented in the "backlash" (11%) and "I belong" (29%) responses, racialized women (23%) and white women (20%) were over-represented in the "engage" responses, and racialized men (76%) and racialized women (71%) were overrepresented in the "ignore/reframe culture" responses, often identifying the problematic behaviours of various actors within and beyond engineering. Please see figure 7 for a composite bar chart of these aggregated findings. Numbers represent the percentage of individuals in each race/gender group who responded in each way.

Figure 7: Response types to aspects of engineering culture that constrain my belonging (n=588)



To illustrate the force with which participants either took up or left behind our prompt, we have shared a sample of illustrative quotations in table 3.

Table 3: What about culture? Participants engage, ignore, and lash out at our prompt (n=588)

Gender/Race	Engage	Reframe/Ignore	Backlash
White men	1c) ERTW "*Some individuals have reflected inflated status just because they are engineers. Sometimes an egotistical sense that only Engineers can solve problems without respect for others that find solutions through other means/avenues."*	4a) engineering is not respected by society "*Lack of public recognition of the engineering profession as an equal to lawyer, doctor etc."*	7a) What do you mean by engineering culture? *"What exactly is engineering culture??? You either want to design, construct, build, and improve things and peoples' lives or not! You are either interested in applied science or not! Getting an engineering degree is 40% brains and 60% raw determination to succeed."* 7d) Woke EDI culture is the problem! *"The shift to woke values prioritizing traitism (the valuing of immutable characteristics over all else), DEI programs that promote people by their characteristics rather than their competence and the shift towards valuing feelings over facts."*
White women	1a) Old boys club mentality *"dude bro business casual boys clubbbb in khakis who play poker together on the weekends. Sometimes the blatantly male culture is too much to deal with."*	2g) Up and out [66, 67] " *My gender is still a gap, especially in certain industries and I don't feel as technically strong as I should, likely due to a career spent almost entirely in supervisory/ management/ leadership roles."*	No backlash to culture prompt in this group
Racialized men	1d) hard work/hard play "*Aspects of the social culture like the presence and the centrality of alcohol in every social event"*	5a) Professional societies as gatekeepers "*Gate keepers of information and agencies like (prof society) that want to define what an Engineer is"*	7a) what do you mean by engineering culture? "*not sure what you mean about engineering culture. To me it is a culture of checking and rechecking and making sure things are right. That isn't making me question belonging in engineering."* 7d) EDI programs miss the point *"Constantly listening to calls for more equity and diversity. I believe that everyone in this country has the same opportunity. It is the unrealistically low expectation of the level of effort required by a young person to achieve their goals that is the issue."*
Racialized women	1a) old white boys club "*The male/masculine dominated aspect of engineering has made me question my belonging in certain spaces, and the racism."*	2b) lack of diversity, especially in senior leadership, being the "only" "*being the only one in many meetings (only woman, only person of colour, etc). people in leadership who don't look at all like me and don't relate to me."*	No backlash to culture prompt in this group

Reading the words of participants in each of the race/gender groups was interesting, not because any one person or any one quotation represents a full group, but because even the same codes can mean very

different things to people across social locations. For example, code 5d addresses unfair advancement patterns in engineering. A racialized woman who made this point said, "the middle-aged white men who manage to fail up bother me sometimes," while a similar aged white man said, "I do not enjoy seeing the promotion and selection of less skilled or capable Engineers based on gender or race." In both cases, participants mourn the absence of merit-based promotion, but their understanding of merit differs. Had this been a forced choice question, with "unfair promotion patterns" as an option, we would have been unable to differentiate the anti-oppressive invocation of merit (white men fail up) from the anti-EDI one (racialized woman get an unfair advantage). Our thematic and critical analysis of 1198 open-ended responses connecting engineering culture to belonging not only teach us about these two aspects of engineers' work, but also about the limitations of forced choice questions and the challenge of accurately interpreting means.

Summary of Findings

Recall the research questions that guided our initial inquiry: RQ1: How does engineering culture enhance and constrain Canadian engineers' sense of professional belonging? RQ2: What kinds of data do we get from whom when we use the social construct "engineering culture" as an explicit survey prompt? RQ3: How can we use these findings for liberatory ends without further alienating marginalized engineering communities? We return to these questions now.

RQ1: How does engineering culture shape Canadian engineers' sense of professional belonging?

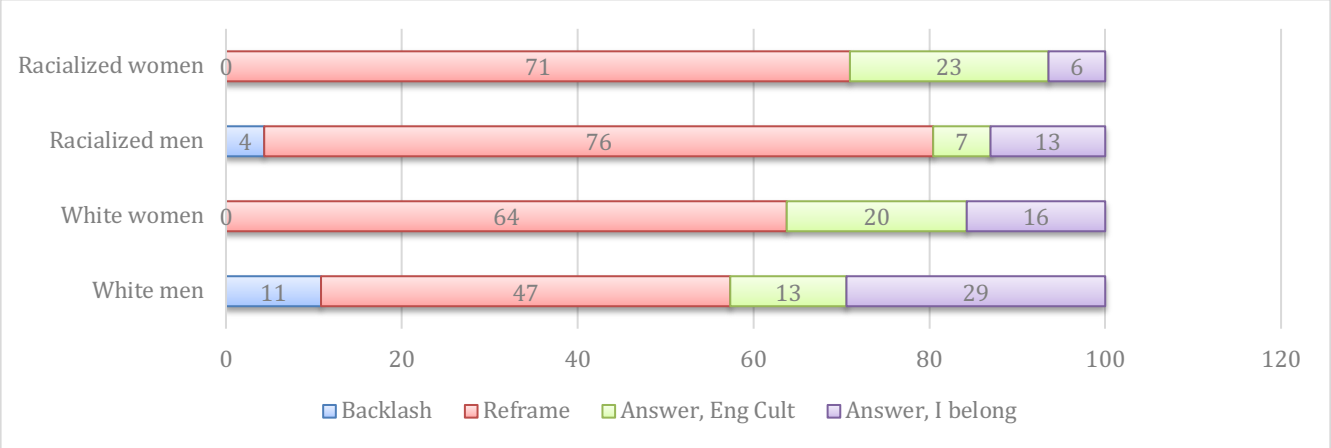
Our thematic coding of two survey questions inviting participants to discuss how engineering culture enhances and constrains their belonging suggests that a shared technical mindset, team-based problem solving, and an alignment between personal and engineering competencies enhances engineers' sense of belonging, while dominant ideologies, poor behaviour of individual engineers, insufficient respect for the engineering profession, and organizational regulation constrain their sense of belonging. While the top three supports were similar across demographic groups, the top three constraints differed by gender and race. Racialized women and white women were over-represented among those who named engineering culture or engineering behavior as a constraint to their belonging, while racialized men were over-represented among those who reframed the question as though we had asked what external factors constrain engineers' work.

RQ2: How do participants respond when we introduce "engineering culture" as a survey prompt?

Our second layer of analysis involved an additional read of question 66 "What aspects of engineering culture cause you to question your belonging?" While the content was interesting, it told us less about how participants responded to our prompt than an analysis of response type. When we coded for response type we found that 14% of participants engaged with the concept of engineering culture as a constraint to their belonging, 8% articulated opposition to our prompt, 54% reframed the question omitting the idea of "culture," and 24% pointed out that they belonged. Stated differently, the most common type of response we got from engineers when we introduce "engineering culture" as a structural factor shaping belonging was a "plain language" reframe of the question. Others suggested that engineering culture did not constrain their belonging, or articulated opposition to the prompt. This suggests that in contrast to researchers who are centrally concerned with reducing social desirability bias,[1, 2, 4] we did not experience a critical mass of participants trying to please us through their answers. For the most part, they took the opportunity to translate the question into their own terms. We could have shortened the survey by removing the two questions with social science prompts, but this would have restricted the opportunity for 14% of participants who did engage with the prompt to speak out against normative engineering culture. While 14% of those who responded to this question only makes up 82 people, many of the individuals in this group were racialized and white women. This leads us to the second part of our research question, "what kind of data do we get *from whom*?" We notice that 23%

of racialized women and 20% of white women engaged directly with the prompt compared to 14% of the sample. On the backlash side of the spectrum, 0% of racialized women and 0% of white women opposed the prompt compared to 8% of the sample. This is an important difference to keep in mind as we find ways to transcend three decades of EDI initiatives centering recruitment and retention. While these initiatives have helped attract more women (mostly white) to engineering programs, they have been minimally effective at reducing structural inequity in the profession. Please see figure 8 below for an illustration of response type disaggregated by our intersectional race/gender category.

Figure 8: Q66—Response types to a social science prompt disaggregated by race/gender (n=588)



RQ3: How can we use these findings for liberatory ends without burdening underrepresented groups?
Our third research question poses a critical, future-oriented inquiry about how we may use our findings for liberatory ends. When we ask questions about engineering culture in our classes, we place a heavy burden on members of under-represented groups to speak up about inequities, exposing them to potential backlash and adding to their emotional labour. This trend continues into the workplace with racialized and white women over-represented among those tapped to take on EDI service loads in their respective organizations.[58] One minor, but significant way to use the findings in this paper for liberatory ends is to retain critical prompts on large scale surveys even if the majority of respondents ignore them. Those who accept them have the opportunity to name what they see, highlighting inequitable practices from the relative shelter of masked identities, while those who oppose them can speak their vitriol into the void. By retaining prompts about "engineering culture," we may amplify the critical responses of those who see systems of oppression everywhere they turn while protecting them from the backlash of those who continue to be advantaged by normative engineering practices. Even if the majority of participants ignore the question, it is worth giving others the opportunity to speak truth to power. While a few conceptually dense survey prompts cannot liberate us from oppressive elements of engineering culture, they may help us amplify the voices and experiences of those who are able to answer the question. Many DEI committees and professional development opportunities provide spaces for everybody to have their say, implicitly reproducing the opinions of the majority (numeric and cultural). Selective reading of a question that explicitly asks people to identify systems of oppression within engineering culture may help us shift the balance. We will then be better positioned to follow up at the institutional level with structures, policies, and processes that enhance belonging of underrepresented groups.

So what? Justice-based argument for retaining social science prompts in engineering surveys
What happens when engineering education researchers introduce social science concepts into our studies as data generation prompts? While it is common for us to ask research questions through conceptual frameworks rooted in the social sciences and humanities, it is less common for us to use these concepts as direct prompts in empirical studies. This may be a product of the polarizing nature of empiricism

which is often a credibility test for positivists and a red flag for critical theorists. If we manage to get past the question of whether empirical studies like large-scale surveys are good or bad for engineering education, we are then faced with another challenge, how to make sense of responses from the majority of engineers who may hear and decode questions differently than social science researchers intended? How can we respect the views of our participants without adopting the analytic tendencies of the majority?

The questions we ask in this paper are not the ones we intended to examine when we initially framed our study on engineering career paths and EDI, and the findings we centre are not the ones we intended to present when we began analyzing responses to Q66. We expected a certain degree of backlash to our questions about equity, and 8% of the sample (all men, mostly white) did not disappoint! But we did not predict the less oppositional reframing of the question. Of the 588 Canadian engineers who responded to Q66, only 82 (14%) answered the question directly. The remaining 506 took time out of their busy lives to respond to this optional, open-ended question while side-stepping the key concept we were inviting them to discuss, either by saying it was a non-issue, or that we were the problem, or that something other than culture was more pressing. We presumed survey respondents would either skip the question entirely or let us know what aspects of engineering culture caused them to question their belonging. The relatively high response rate to a reframed version of the question surprised us, but it may help explain why EDI conversations and PD sessions are so easily derailed. It does less to highlight the advantages and disadvantages of integrating critical social science prompts into engineering surveys. We now turn to this question.

If we keep conceptual gems like “engineering culture” to ourselves, leaving the survey in “plain” language, we may increase participant response rates and the power of statistical tests, but we also run the risk of masking important insights expressed by those who bang into engineering culture daily. We can always ask more generic and accessible questions on our surveys, inviting participants to “explain” their ratings, but by leaving out social prompts like “engineering culture,” we lose access to the collective wisdom of participants who understand these questions and use them as an opening to read normative practices. Our previous analytic habit was to apply our own critical lens to the full set of responses after collecting them, using critical theory to generate a strong counter-narrative. While this practice can produce powerful insights about dominant engineering ideologies, it may be too neat to reflect the full range of experiences, sensemaking processes and agency of practicing engineers.

The issue with “plain” language approaches recommended by experienced survey researchers in engineering education, is that it is not actually “plain.” Rather, it is intelligible to the majority of engineers because it is drawn from normative discourse in the profession. Recall the quote we shared earlier in this paper in response to Q65 (What aspects of engineering culture make you feel like you belong?). The participant who answered this question said, “I find that interacting with fellow engineers is far easier than other non-technical people. My brain doesn't have to work as hard to communicate on a level they understand.” Easily decoded questions may be more accessible to engineering practitioners as a whole, but the use of terminology exclusively drawn from dominant engineering discourse will implicate us in reifying structural inequities in engineering culture, reflecting Spivak’s [5] argument that the subaltern cannot speak. That is, if we remove critical prompts from a survey in the name of accessibility, we restrict the intelligibility of critical speech. In contrast, by including critical, socially constructed prompts, we provide space for “multi-lingual” respondents to call out oppressive structures embedded in normative engineering culture. We believe this gain is worth the risk of inconveniencing participants who need to reframe the question to make it intelligible to them, and even worth the risk of angering a small, but vocal group of insiders who feel unsettled by the question and like to lash out in ALL CAPS. When this kind of backlash happens in a classroom, workshop, or professional practice

setting, the facilitator typically stops to address the interruption, implicitly reproducing normative engineering culture. We are suggesting something different. Instead of interrupting socially just change to pacify the needs of those who prefer to defend current practices, we can use their backlash to signify that something is going on. Once we get this signal, we can turn our attention to the voices of those who see social science prompts as an invitation to articulate what they have known all along. This is much easier to do when analyzing a survey than when teaching a class because we are not responsible for supporting the development of all survey respondents, and because we have more time to formulate a response.

Returning to the wisdom of cultural studies theorist Stuart Hall, we believe that culture is made and remade, shaped, and reshaped all the time by community insiders and outsiders, but not from scratch. It happens in response to durable, normative narratives and practices operating in and through broader ruling relations. Framing engineering culture as a barrier to belonging in the engineering profession is one way to resist the "historic inertia"[8] of dominant narratives. When we minimize the ambiguity of survey prompts, we adopt a standard set by the white, male majority, leaving dominant ideologies and engineering culture intact. In contrast, when we integrate critical social science concepts into our surveys, we provide a small opening for those who see ruling relations to articulate their vision. When we follow up on their recommendations with institutionally durable accountability mechanisms, we open a small window for liberatory practice and meaningful change.

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