Women in Graduate Engineering Programs - Why aren't there more of them?

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Full Research Paper
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Abstract

Medical, veterinarian, and dentistry graduate schools in Canada started to graduate equal numbers of men and women during the 1990s; however, the proportion of women graduating from Canadian graduate engineering programs in 2022 was only 27%. This paper examines graduation trends from Canadian graduate engineering programs (GEPs) from 2000-2019 focusing on gendered differences in graduation rates. It also examines students' and faculty's experiences at two large graduate engineering schools and discusses how women's experiences differed from men's. Qualitative results from interviews exploring the experience of faculty and students within GEPs were used to illuminate gendered graduation data from these programs.

Quantitative findings indicated the proportion of women graduates from GEPs increased by only three percentage points over 20 years, and the proportion of women was consistent across domestic, international, full-time, and part-time cohorts. During interviews, women discussed discrimination, problems reconciling parental and professional roles, and being ignored or tokenized. All women students enjoyed their studies but had experienced or witnessed sexism within their graduate programs which diminished their sense of belonging to their program and profession. Both women and men described instances of colleagues ridiculing or resisting Equity, Diversity, and Inclusion (EDI) initiatives.

Two theorists were used to analyze and frame results. Suchman's model of institutional legitimacy, which holds that institutions strive to maintain three types of legitimacy: cognitive, moral, and pragmatic, to justify their existence and support their reputation, was used to examine organizational actions and culture. Bourdieu's concept of habitus was used to investigate participants' sense of belonging in GEPs. Recommendations included increasing the visibility of senior leadership on EDI initiatives and addressing the existence of internal systemic problems.

Introduction

Many professional schools in Canada began to graduate equal numbers of men and women in the 1990s, such as medicine [1], dentistry [2], and veterinarian [3] schools. However, the number of women graduating from GEPs in 2019 was only 26% [4]. In contrast to the relatively low number of women graduates from GEPs, public discourse supports increasing the number of women within engineering. Academia [5], industry [6], and government in Canada [7] are united in seeking to increase the number of women in the engineering profession but there remains a gap between this aspiration and the reality within the profession. This paper explores why a similar gap exists between public discourse and the actual long-term graduation rates from Canadian graduate engineering schools and the experience of students and faculty within these programs.

Studying GEPs in Canada is important as GEPs are a critical source of new women engineering leaders in industry and the only source of new women engineering leaders in academia. Increasing the number of women leaders in engineering, for both industry and academia, will weaken masculinist norms around leadership in the profession and provide role models for aspiring engineers. Research focused on GEPs is also needed as both quantitative and qualitative

research within engineering education has focused on the undergraduate level within the US environment, and we lack studies addressing the unique needs of graduate engineering students in Canada, with a few notable recent exceptions [8, 9].

Using quantitative and qualitative data collected and analyzed from a larger research project, this paper seeks to answer the following two research questions:
1. How has the proportion of women graduating from Canadian graduate engineering programs changed over the period 2000-2019 at the national and institutional levels?
2. Do participants perceive GEPs as having "chilly" environments and, if so, how does "chilliness" manifest within Canadian GEPs?

Literature

While we know that the number of women employed in STEM within Canada is increasing, they are less likely to work in STEM fields than men, tend to be overrepresented at lower levels, make lower salaries, and do not have as many opportunities for promotions in STEM careers as men [6]. Women working in Canadian engineering schools face similar challenges. Women represented less than 17% of engineering faculty in 2019 [10] compared to 41% of all faculty at a national level [10] and were overrepresented at junior levels [4]. Canada is not the only country that experiences difficulties attracting and retaining women in Engineering. Other countries experiencing similar difficulties include the US [11], Australia [12], the UK [13], and various European countries [14].

Literature informing this study includes research examining and theorizing how organizational culture informs individuals' experience and sense of belonging within those cultures [15, 16, 17, 18], how organizations' claims of legitimacy influence their environments [19], and how EDI initiatives may involve both intended and unintended consequences for organizations and individuals [20]. Certain scholars have claimed that many organizations are gendered entities that limit women's success by incorporating male norms. Acker [21] argues that organizations are gendered in that they assume an ideal employee who is male and without family responsibilities. Organizations' policies and processes then embody this "ideal" employee which, in turn, reinforces masculinist norms, making it difficult for anyone who does not identify as male and/or has family responsibilities to succeed within these organizations [21, 22].

Focusing on organizational culture in engineering, many scholars have claimed that cultures within engineering organizations can be uncomfortable or hostile for women and can cause women to either consider exiting or avoid the field [23, 24]. Engineering environments are described as being chilly, where individuals who identify as women and other underrepresented groups perceive they are tolerated rather than included within the community [23]. Hatmaker, [16] describes various behaviors of men that can chill the environment for women in engineering and Cech has documented how processes are gendered within engineering environments [17], which negatively impacts women's success within the profession and weakens their sense of belonging. Other scholars have also noted how humor is often used by dominant groups in engineering, and other fields, to stress the exclusion of minority groups and perpetuate sexist and racist behavior [23, 24].

However, while there is a robust body of literature examining the impact of chilly environments on undergraduate students, students within graduate programs are rarely the object of study, despite grappling with different challenges than those that face undergrads. Compared to undergraduate students, graduate students represent a higher per-student cost to the organization, are far more likely to have dependents, and be employed while studying [25]. This paper aims to add to the literature on graduate students' experience and our knowledge of gendered graduation trends in Canadian GEPs and how chilliness manifests itself in GEPs and is experienced by women in these programs.

This paper uses the Government of Canada's research funding definition of EDI [26], which stresses removing systemic barriers, respecting individuals' unique dimensions, and valuing contributions from all individuals involved in research.

Theoretical Framework – Suchman's Model of Organizational Legitimacy and Bourdieu's Concept of Habitus and Sense of Belonging

I have used Suchman's work on legitimacy in this paper as it provides a framework to examine, and potentially explain, the nature of organizational behavior [19]. Suchman's theories have been used to examine organizational dynamics in many sectors; to examine how Canadian universities' strategies are impacted by rankings [27], to analyze access within Ontario universities [28], and to analyze how organizations react to climate change [29].

Suchman [19] maintains that all organizations strive to achieve legitimacy to justify their existence while building and protecting their reputations. Suchman posits that organizations strive to attain three types of legitimacy: cognitive legitimacy, pragmatic legitimacy, and moral legitimacy. Organizations typically pursue all three types of legitimacy, often concurrently, and as shown in Figure 1, these forms of legitimacy can intersect, complement, or contradict each other.

For universities and colleges, cognitive legitimacy comprises the institution's academic reputation or the desire to be the best in the field, be that research, teaching, or a specific knowledge area. Cognitive legitimacy is more difficult to achieve than the other two forms of legitimacy in Suchman's model, in part because it takes time to establish an institutional reputation and the traditions that support it.
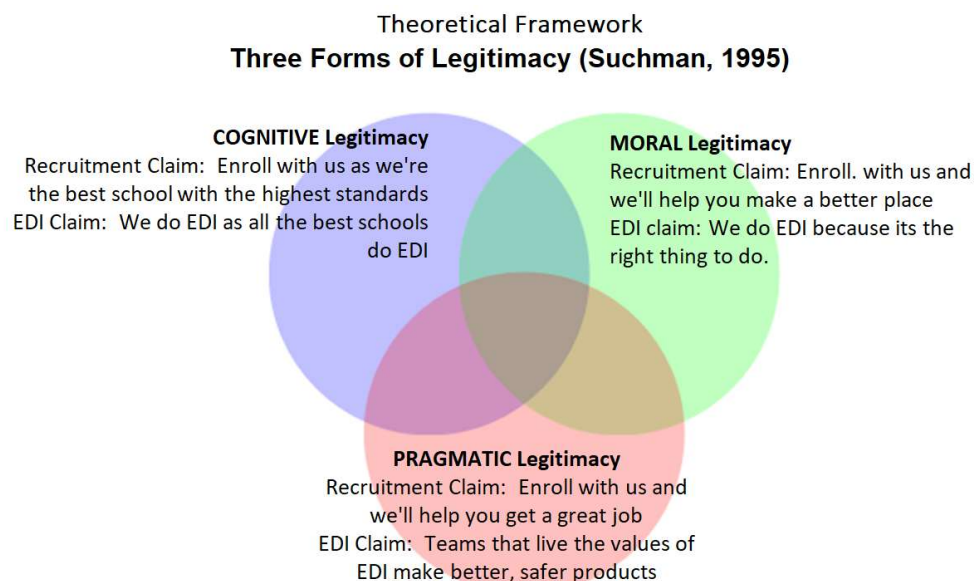
A university possessing high cognitive legitimacy could be defined as an institution with extremely selective admission criteria, a long history of research excellence, and be acknowledged to be the best in its field. Universities claim cognitive legitimacy by communicating high-ranking scores, the rigor of their admission process, their research achievements, or claiming excellence within a specific knowledge area or profession. A university with high pragmatic legitimacy could be defined as an institution that provides students with a comprehensive education and prepares them well for the workforce. Universities claim pragmatic legitimacy by highlighting their high post-graduate employment rate, their administration's ability to provide students with good value for their tuition fees, or their support of local industry through their research activities. A university with high moral legitimacy could be defined as an institution that "does the right thing", and whose members work to benefit

society. Universities wishing to establish their moral legitimacy could make claims that draw attention to programs that help students make the world a better place, to their EDI initiatives or scholarships designed to support underrepresented groups and recognize community volunteer work done by faculty, staff, and students.

Suchman also notes that claims for legitimacy require an audience to receive and validate them and organizations may choose to make different claims to different audiences depending on the type of legitimacy they are seeking to establish, and the relationship the organization has with that specific audience. Figure 1 below shows how different claims could be used to establish legitimacy for different audiences. In Figure 1, a university makes claims of legitimacy on two types of web pages: recruitment and admission. Claims made on admission webpages (recruitment claims) are targeted to an audience of students. Claims made on EDI webpages (EDI claims) are targeted to an audience of EDI supporters.

When looking to establish pragmatic legitimacy for students, a university could claim on admission webpages that if students take a degree at their institution, they will obtain an excellent job. When looking to establish pragmatic legitimacy for EDI supporters, a university could claim on EDI webpages that teams who live EDI values create better, safer products through diverse teams.

Figure 1: Suchman's Model of Organizational Legitimacy Applied to Universities

Theoretical Framework
Three Forms of Legitimacy (Suchman, 1995)

COGNITIVE Legitimacy
Recruitment Claim: Enroll with us as we're the best school with the highest standards
EDI Claim: We do EDI as all the best schools do EDI

MORAL Legitimacy
Recruitment Claim: Enroll. with us and we'll help you make a better place
EDI claim: We do EDI because its the right thing to do.

PRAGMATIC Legitimacy
Recruitment Claim: Enroll with us and we'll help you get a great job
EDI Claim: Teams that live the values of EDI make better, safer products
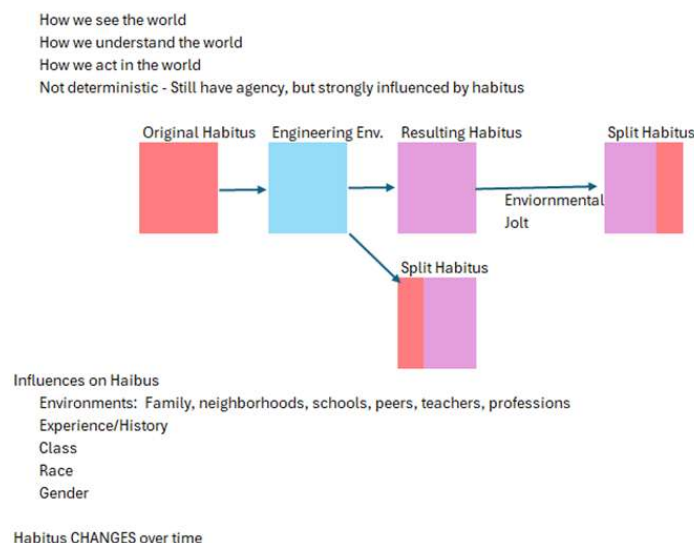
Suchman notes that claims to support the three forms of legitimacy can conflict with each other, especially in times of social change, and notes that organizations may experience difficulties in managing these conflicts. This issue is pertinent to this paper, as certain actors in higher education perceive the moral legitimacy of EDI initiatives as undermining the cognitive legitimacy of academic rigor, as these individuals conflate adherence to EDI principles with a dilution of academic standards [30]. At a higher level, Suchman's theories are useful to this research as they explain how organizations strive to establish various forms of legitimacy, how

these actions influence organizations' behavior and culture, and how they react to internal and external changes.

In both *The State Nobility* [31] and *Homo Academicus* [32] Bourdieu, a French sociologist, investigated how higher education promoted social reproduction in the 1980s and 1990s. Based on this research, Bourdieu argued that higher education systems protected the status quo and legitimized actors in positions of power; facilitating the success of middle and upper-class students. He also claimed that those disadvantaged by the system, such as working-class students, were persuaded by their experience within these systems that the status quo was a natural and justifiable state of affairs. Bourdieu's theories can help us understand why, despite efforts to increase diversity and promote gender equity, senior positions within industry and academia in engineering are predominantly held by individuals who are male and white and why engineering school cultures are often characterized as being competitive, meritocratic and individualistic [31]. Bourdieu is not deterministic and does not deny the possibility of change, but he does argue that effecting change within fields is difficult as people in positions of power will contest, both consciously and unconsciously, to maintain the status quo [29, 30].

In addition to examining power dynamics within institutions, Bourdieu also analyzed and described how students from different class backgrounds reacted to the environments within universities. Bourdieu used a concept he termed *habitus* to define how he believed individuals experienced the world and how those experiences and past histories informed the identity, disposition, and behavior of individuals. He also argued that habitus influences how people navigate and succeed within different environments. Bourdieu maintained that upper-class students would typically have a habitus influenced by parents and relatives who have attended university, benefitted from academic tutoring, and possess an extensive network through family and friends to help them choose the right program in the right school, then later help them find suitable employment. All these advantages facilitated the success of upper-class students within the elite French universities that Bourdieu studied.

Figure 2: Development of Bourdieu's Split Habitus over Time

Habitus (Bourdieu, 1985)

How we see the world
How we understand the world
How we act in the world
Not deterministic - Still have agency, but strongly influenced by habitus

Original Habitus   Engineering Env.   Resulting Habitus   Split Habitus

Enviornmental Jolt

Split Habitus

Influences on Haibus
Environments: Family, neighborhoods, schools, peers, teachers, professions
Experience/History
Class
Race
Gender

Habitus CHANGES over time

In contrast, working-class students may not have had any of these advantages influence their habitus which led them to feel less at ease within university programs and less likely to succeed. This lack of ease experienced by working-class students Bourdieu terms a *split habitus* (see Figure 2) because students who came from a working-class habitus experienced a sense of dissonance between what they perceive themselves to be, and their perception of what a successful student needs to bring to their program. In other words, their sense of belonging is reduced as their habitus and personal values conflict with the norms within a university environment.

Bourdieu does not contend that having a working-class habitus dooms working-class students to failure, but argues that coming from a working-class background, as he did, does make succeeding within academia much more difficult. In this paper, I use the concept of split habitus to examine how gender within habitus can lead to a sense of dissonance between personal values and the values enacted within GEP environments causing women to experience a sense of split habitus.

As the focus of this paper is gender rather than class, it should be said that while Bourdieu's theoretical framework's predominant focus is class, scholars have found his concepts useful in feminist studies [34], using them to examine the role of gender in such diverse fields as: construction, engineering architecture [23], snowboarding and surfing [35], nursing, social work [36] and academia [37, 38].

Scope and Limitations

Results discussed in this paper were obtained in a larger three-phase research study [38] that investigated why gender equity in engineering has not been attained in Canadian GEPs, despite prevailing public discourse that strongly promotes having more women within engineering. Phase 1 of the study examined enrollment and graduation data in all Canadian graduate engineering schools 2000-2019, to establish longitudinal patterns at a national and institution level. Phase 2 analyzed trends in the public discourse by examining website content at 10 large Canadian engineering schools. Phase 3 focused on the experience of faculty and students within GEPs at two large Canadian engineering schools. This paper focuses on results obtained in Phase 1 and Phase 3.

In this larger study, I was the sole researcher and, as such, collected and analyzed all data used by this paper, and recruited and interviewed all participants. I am a middle-class, white student that had a career in software development for over 25 years before returning to graduate school. I was born into a working-class family in England, moved to Canada as a teenager, was the first in my family to attend university, and completed my MBA part-time while working full-time and raising a family. My position of privilege as a white middle-class individual and my experiences within industry and graduate school as an immigrant and a first-generation student have influenced my research interests and my perspective as a researcher.

This paper includes results obtained from statistical analysis that occurred in Phase 1 and interview data obtained in Phase 3 of the larger study. This paper focuses on gendered trends in historical graduation patterns at the national and institutional levels established in Phase 1, and

emphasizes results derived from interview data, collected in Phase 3 pertaining to students and faculty's sense of belonging and if and how their experiences reflected chilliness within their GEP's culture and environment.
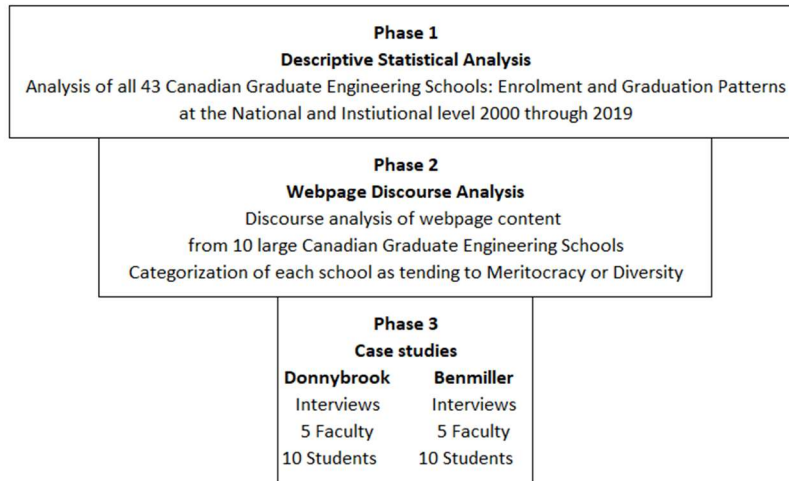
As my qualitative results focus on the processes and cultures within two Canadian graduate universities these findings are specific to these schools at a particular point in time and therefore cannot be generalized to other schools and other countries. However, arguably the findings are of interest to practitioners in other graduate engineering schools and can be used to frame and inform studies in other graduate environments and geographies, generate recommendations for practitioners, and extend the application and understanding of the various theories employed by this study. For the quantitative data results, data used by the larger study is publicly available [4] and methods used to calculate results are documented [38] but while the quantitative results can be replicated, they remain specific to the Canadian environment.

This research has limitations concerning participant recruitment, language, and interview data. Recruitment emails explicitly invited individuals to participate in a study that sought to examine gender equity in GEPs. As participants who accepted the invitation were knowingly participating in a study focused on gender equity in engineering, results could overstate both knowledge of, and support for, gender equity within Canadian GEPs. From a language perspective, I do not speak French well, therefore had to exclude two of the largest Canadian engineering graduate schools, ETS and Polytechnique as these schools use French as the language of instruction. Consequently, both schools were excluded from the selection process for the website analysis in Phase 2 and case study sites for Phase 3. This means that the research lacked a Francophone perspective on the public discourse surrounding gender equity in engineering. 30 interview participants were interviewed during phase 3, and the data is specific to the place and time of data collection and is qualitative and I do not claim these results are generalizable; however, the data could still be useful to practitioners in providing alternate perspectives and additional information on the experiences of faculty and students in GEPs.

Methods and Research Design

As noted above, this paper is based on results from a larger study and uses statistical analysis conducted in Phase 1 and interviews conducted in Phase 3 of that study. Figure 3 below is provided to help situate the findings discussed in this paper within the context of the overall study.

Figure 3. Overall Research Design for the Three Phases of the Overall Study

Phase 1
Descriptive Statistical Analysis
Analysis of all 43 Canadian Graduate Engineering Schools: Enrolment and Graduation Patterns at the National and Instiutional level 2000 through 2019

Phase 2
Webpage Discourse Analysis
Discourse analysis of webpage content
from 10 large Canadian Graduate Engineering Schools
Categorization of each school as tending to Meritocracy or Diversity

Phase 3
Case studies
Donnybrook	Benmiller
Interviews	Interviews
5 Faculty	5 Faculty
10 Students	10 Students

As discussed above, Phase 1 aimed to identify graduation and enrollment patterns indicating variations by gender and institution. Data for Phase 1 was obtained from Engineers Canada's Enrollment and Degrees Awarded report 2000-2019 [4] Statistical data analysis at the national level, included all 43 graduate engineering schools, with a comparative analysis performed at the institutional level addressing 10 of the largest graduate engineering schools. Phase 2 performed a discourse analysis on websites belonging to the same 10 graduate engineering schools to capture the public discourse and categorize each school as tending to meritocracy principles or diversity principles. Phase 3 included semi-structured in-depth interviews conducted within two case studies with 10 faculty and 20 student participants. One of the schools selected for the case studies was an elite, research-based institution; the other school was a teaching-focused institution with less stringent admission criteria. Pseudonyms were used for both individuals and universities to protect individuals' privacy and anonymity. The pseudonym used for the research-focused school was Donnybrook and the one used for the teaching-focused school was Benmiller.

10 faculty and 20 students were interviewed. Please see Appendix 1 for more information on participant demographics at each school. Participants represented both research and course-based degrees and various levels of study. Recruitment of students was done via emails sent by administrators within the engineering faculty and recruitment of faculty was done directly through departmental emails found on websites. Students were given a $30- gift card to compensate them for their participation. Data collection activities during this study were approved by Ethics Review Boards (the Canadian equivalent of an IRB in the US) at the University of Toronto, Donnybrook University, and Benmiller University.

All interviews followed a semi-structured format, were approximately an hour long, and were conducted in 2022 over Zoom [39]. At the beginning of data analysis, all transcript data was read by myself, to validate data and refresh my understanding. The interview data then was entered into an iterative three-stage coding process. Firstly, inductive coding and then deductive coding to ensure categories created in the initial stages remained useful and effective. My theoretical framework was then used to inform a third pass of the data [40]. I then grouped data categories

by theme and performed a thematic analysis. A relativist perspective was used to identify the differences and similarities amongst institutions, and across roles and gender.

Results and Discussion:

In this section, I will review the quantitative results on the proportion of women in GEPs and results derived from interview data collected from faculty and students, and discuss the findings using both Suchman's [19] and Bourdieu's [29] work to theorize these findings, explore their implications and answer the research questions posed by this paper.

Quantitative Results: Women graduating from GEPs at the national level:

From 2000 to 2019, the number of graduates from Canadian graduate engineering schools increased by 341% [41] more than double the national growth rate of graduates from all graduate programs by 147% [41]; however, growth in the proportion of women graduating from GEPs was not rapid. The proportion of women was 23% in 2000 but only increased to 26% in 2019 [4], as can be seen in Figure 2. Within the national data, various populations had similar proportions of women and consistent growth patterns when compared to the overall national numbers. The proportion of women as a percentage of the total domestic population, as a percentage of the international student population, and as a percentage of the part-time student population was within 1 or 2 percentage points of the overall national average of 26% [4].

Figure 4. Comparing Women and International Students' Number of Graduates and Proportion of the Graduating Class Over the Period 2000-2019
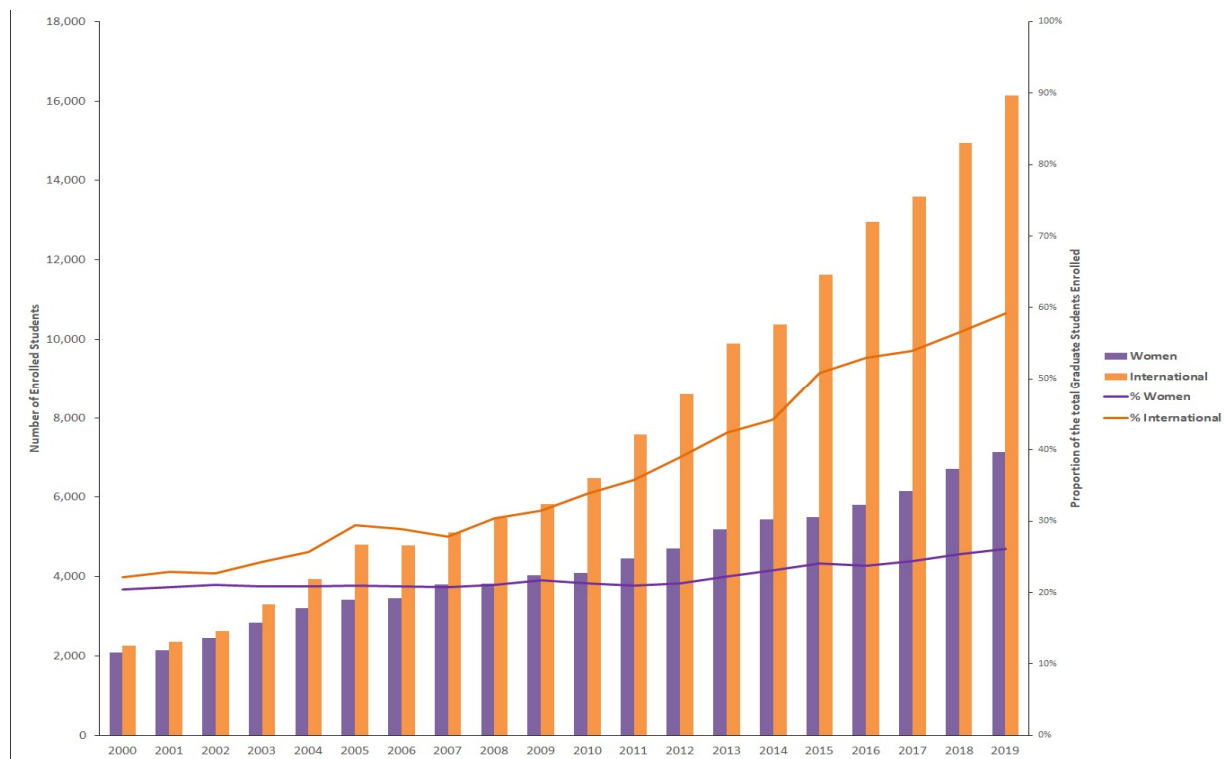
Data derived from Engineers Canada [4].

In contrast, international students as a proportion of the graduating class from GEPs grew very quickly over the period of 2019, and by 2019 the proportion of international students was over 60% percent (See Figure 4 above). This figure highlights both the strong growth in international students (left Y axis) and the proportion of international students (right Y axis) and compares it to the slower growth in women's numbers.

Many external factors contributed to the growth of international students within GEPs in Canada. Tuition for international students was deregulated in the late 1970s providing additional revenue streams for GEPs which was badly needed given government spending declined in real terms over 2000-2019 [42,43]. Immigration policy changes in the 1990s encouraged prospective immigrants to take graduate degree programs, and the increased international mobility of all students allowed Canadian GEPs to recruit students at a global level. However, while there have been multiple external factors that encouraged the growth of international students, these patterns provide an interesting contrast to the slow growth shown in the proportion of women students and demonstrate that change can happen quickly in GEPs graduation demographics depending on context.

Another finding of interest is that the proportion of part-time students declined throughout 2000-2019, from 24% to 8%, while women as a proportion of part-time students remained between 24-26% during 2000-2019.

Quantitative Results: Women graduating GEPs at the Institutional Level:

From an institutional perspective, the proportion of women in GEPs grew at nearly all schools, but the change in proportion over time differed amongst the 10 schools that were included in the institutional analysis. Please see Table 1 below for details.

Table 1. The Number and Proportion of Women in GEPs in 10 Large Canadian GEPs Comparing 2000 to 2019.

	2000		2019		Comparison 2000 vs. 2019	
	Number of Women	Proportion of Women	Number of Women	Proportion of Women	Change in Number of Women	Change in Proportion of Women
Alberta	18	14%	121	28%	103	14%
Calgary	15	17%	102	29%	87	12%
Concordia	12	14%	277	26%	265	12%
McGill	35	26%	89	27%	54	1%
McMaster	28	28%	108	29%	80	1%
Ottawa	18	20%	135	29%	117	9%
UBC	55	27%	140	29%	85	2%
Waterloo	38	25%	217	29%	179	5%
Western	11	23%	104	27%	93	4%
Windsor	12	27%	165	13%	153	-13%
NATIONAL	534	22%	2,684	25%	2,150	3%

Data derived from Engineers Canada [4].

Table 1 compares the change in the proportion of women in the graduating class from 2000 to 2019 at 10 of the largest Canadian GEPs. The table is sorted in descending order based on the results in the last column which contains the change in percentage points in the proportion of women graduating from that university's GEP when comparing 2000 to 2019. Table 1 shows that one school, Windsor, saw its proportion of women drop by 13% over this period. Another three schools' proportion of women graduates changed less than the national average of three percentage points, with six of the schools exceeding the national average. In contrast, engineering faculties at Alberta, Calgary, and Concordia's GEPs succeeded in changing the proportion of women within their GEPs by more than 10 percentage points from 2000-2019. [4]

Quantitative Results: Theorizing Results and Discussion

From a theoretical perspective, Suchman's model of legitimacy [19], could be used to argue the results indicate that Canadian GEPs have shifted resources to increase their pragmatic legitimacy by seeking additional forms of revenue from international students. The efforts to achieve pragmatic legitimacy in terms of increased revenue appear to have been greater than the resources applied to obtain increased moral legitimacy by achieving substantive increases in the proportion of women graduating from GEPs. An alternate explanation using Suchman's model is that actors within GEPs may conflate EDI initiatives with a dilution of academic rigor, thereby threatening cognitive legitimacy. This may lead to EDI initiatives being performative rather than substantive. The finding that the number of students enrolled in part-time students has remained flat, despite the strong growth experienced in GEPs, could be theorized as part-time students are perhaps less likely to be perceived as contributing to an organization's claims of cognitive legitimacy, or from a pragmatic legitimacy perspective, it could be that part-time programs are more expensive to run than full-time programs in GEPs. This finding does seem counter-intuitive given the rhetoric of lifelong learning within the engineering profession and limits GEPs' ability to offer a pathway that allows students to pursue their studies while working full-time or taking care of family members.

From an institutional perspective, the finding that the proportion of women in GEPs has seen little change over time would be consistent with Bourdieu's arguments that systems of higher education work to reproduce privilege in society and that actors within universities work to preserve the status quo [32]. However, Bourdieu did argue that if elite schools were to face an increase in demand, they would react by raising their admission requirements to keep enrollment constant, rather than increasing enrollment [32]. This specific argument is not consistent with the strong growth in GEP graduates in Canada from 2000-2019, either at the national or the institutional level.

Qualitative Results: How Chilliness Works within GEPs.

This section reports and discusses how women experienced chilliness within their environments through the language used within them. It then analyses how the behaviour of supervisors and colleagues together with processes within their environments communicated to women in GEPs that family responsibilities are seen by others as being incompatible with being a successful

engineer. It also reports how backlash to EDI has hurt both women and men participants within GEPs.

Male Norms Decrease Sense of Belonging

Participants described how successful women students were seen as an exception and often had to work hard to have their work acknowledged and their leadership recognized. A student from Donnybrook noted how when her male teammates commented positively, it was often undermined with a humorous aside. She notes "[they] give you a compliment, but it… has the undertone that you're smart for a girl."

Another participant related how vendors automatically assume a male in the room is the project lead.

> Even though at this point I'm the senior student on the study… the one they've been communicating with… they come in and… start explaining things… [to] the nearest male student. There's, there's just an intimacy that I think is very clearly the transfer of knowledge just seems to more naturally flow off, from man to man. *Student 2, Donnybrook*

Other participants noted the camaraderie amongst men that was not extended to women in their lab. Student 11 believed "It's always easier for men... there are more men in this field, so there is... the men's club…they help each other… they have their own language" *Student 11, Donnybrook*. Even Student 3, who believed that she had not personally experienced discrimination based on gender, observed that "all the other men… they help each other without saying anything. If you're a female… you're not going be in a group like that… You're not going to get the same [support]" *Student 3, Benmiller*.

Family Secrets: Don't Ask, Don't Tell

Women participants, both students and faculty, reported incidents of challenges faced by women with family responsibilities in graduate environments. Participants reported students hiding the fact they were mothers, women PhD students being told they should be at home with their child, pregnant women facing difficulties finding support, and expectations that pregnancy would disqualify an individual for a senior position.

Student 3 noted that she believed fellow students chose to hide that they were considering starting a family or were parents. She subsequently clarified that only women students felt it necessary to hide the fact that they were parents (Student 3, Benmiller).

> Student 3: I find most people are hiding it, hiding, being a parent. Hiding their thoughts about being a parent…

> Interviewer: Do both men and women hide it?

> Student 3: No, not men at all. Yes. Not, not at all. Not even for one minute… that part we still have to work on, as a society. Right? But yes, you got it <laugh>. You got it.

It is of note that the student believes this is a societal issue rather than an institutional issue, which would imply that she believes women conceal their parental status within all workplaces and that while it is unfortunate women need to do this, she believes this situation is common. Please see Appendix II for a summary of government benefits paid and weeks allowed for parental leave in Canada. Of interest, one study of academics in Australia and the UK [44] and another global study [45] found that women in academia often worked through formal maternity leave due to productivity pressures and managerial expectations, thereby negating the intent of parental leave policies and regulations.

Student 1 from Benmiller recounted how one of her professors had been told by a colleague that it was inappropriate of her to pursue a PhD when she had a child, while Student 11 from Donnybrook, who had children while completing her doctoral degree, was irritated by the lack of flexibility in working hours which impacted her ability to successfully balance her research and family responsibilities. One professor, the first individual in her department to take parental leave, spoke about the difficulties she experienced determining what policies were in place and how best to plan for her leave. This professor noted that she received very little support and perceived that pregnancy was viewed by her administration as an individual problem that a pregnant person had to "solve", and the institution acted as if had no responsibility to ensure information and support were available.

> You have to... find out what resources are available... those policies exist in some book somewhere, but nobody in the department knows them... it's your problem because you are pregnant, you have to find [the policy] ... it's not the institution's role to support, it's your role to seek and find it. *Professor 8, Donnybrook*.

While women discussed the negative stereotypes associated with family responsibilities more frequently than men, male participants also raised concerns about discrimination against women who chose to have a family while pursuing a career in engineering. Professor 9 at Donnybrook noted that he often had to deal with his colleagues' resistance to EDI principles and worried that he was not being aggressive enough in defending these principles. In the quote below he recounts how he attempted to make a colleague aware of the sexist stance implicit in his assumption that pregnancy would disqualify an individual for an executive position.

> He said, "Isn't she pregnant? Surely, she can't have an executive position now" <laugh>, and I'm there saying "Hey guys, you know, no... come on guys... get with it"... even when I say that, I don't think anybody hears it... maybe I have to cut my hair or something and be a bit more authoritative *Professor 9, Donnybrook*.

In this instance we see an ally being uncomfortable calling out sexist comments, potentially alienated for doing so, and then his discomfort compounded by his concern that his efforts to change his colleagues' behavior are ineffectual.

While the actions described above could be expected to have a chilling effect on women who are pregnant and/or parents, they could also be potentially seen as discouraging for women considering having a family. There is also the possibility that women who have no intention of

having a family may resent the assumption rule that motherhood is something that is tolerated at best and a professional liability at worst. In the instances discussed by participants, parental leave appears to be an individual's problem rather than a right that Canadian organizations have a legal responsibility to provide. Administration within graduate engineering programs may also be missing the opportunity to increase the individual's sense of belonging to the institution and their desire and ability to return to the workplace by inadvertently making their leave and return to their program problematic, thereby increasing the risk of an individual leaving the organization.

On a positive note, both Donnybrook and Benmiller had on-campus daycare that two women students had used during their doctoral studies and who praised the proximity and the level of service (Student 11, Donnybrook; Student 14, Benmiller) which could be assumed to have increased their sense of belonging within their GEP. However, the seven women participants who discussed family responsibilities all believed, to a greater, or lesser extent, that having a family is detrimental to a professional image and success within the field of engineering. Professor 4 summarized her views on this issue as follows:

> Most of the women engineers who've, you know, achieved, you know, upper levels of management and that kind of stuff, they are not married, do not have children, [do not have that] family piece. *Professor 4, Benmiller*.

Backlash to EDI

The backlash to EDI policies and initiatives impacted many of the participants in this study, students and faculty, women and men. Learning that peers believe that equity problems did not exist within their environments and negative reactions to EDI initiatives or learning caused participants to question their sense of belonging to the engineering community within their GEP.

Student 18 recounts her surprise at learning that many of her classmates believed that there were no barriers to women's success in engineering.

> A professor [who was] very progressive…he started a class discussion… [by asking] what do we need to do to encourage women to succeed [in engineering]? And the consensus of the class was that nothing needs to be done… no problems. And that was a really surprising conclusion to me… the numbers show that there aren't many women in engineering… there's a huge problem of attrition [with] women in engineering… on a system level [and] I thought wow, people actually still think that there's not a problem. *Student 18, Donnybrook*.

A faculty member was surprised and disappointed at her peer's reactions to EDI training that was provided to help faculty complete the EDI requirements within Canada's National Sciences and Engineering Research Council grant applications.

> the old timers… keep complaining that "what, I should go to a shop and just pick a lesbian and pick a gay man"... [but I think] no, this is not about that… you are not going to pick people based on their [sexuality]… I was [also] thinking are you for real? Are you telling me that this is what you took from all this training? *Professor 5, Benmiller*.

In both instances, we see individuals realizing that their beliefs and reactions are very different from their peers. The student recognizes that everyone in her class believes that women face no gender-based challenges in engineering, and the professor is frustrated that her peers use humor to undermine EDI initiatives and trivialize EDI requirements. The dissonance between the individuals' values and those of their colleagues can contribute to individuals feeling alienated from their peers and believing they are outsiders in their communities [24].

A PhD student was asked by her supervisor to review the EDI section of his grant application. In the application, the supervisor stated that the lab had "balanced gender representation" *Student 2, Donnybrook*. At the time the lab consisted of two women and six men. The student was then put into the uncomfortable position of having to provide feedback on this error and wondering why her supervisor would make such a statement on a grant application. In this situation, the student became aware there was a disconnect between the supervisor's male perspective of the team and her own.

Participants who were men also experienced feeling distanced from their colleagues due to the introduction of EDI initiatives and advised caution in how their male colleagues were approached. One professor was worried that EDI initiatives had antagonized colleagues and warned that "if we want to try and address discrimination of any form, whether being a woman or… sex or gender and so on… it has to be done in a way that you know, we are not making more enemies *Professor 7, Benmiller*. Another professor stressed the importance of encouraging men if they were to act as allies. "Being critical about men is, is not probably the optimum way to do it. Yeah. Mean they need to be criticized, but they need to be also, you know, jollied, they need encouragement… we need somebody to say, yeah, you're doing a good job" *Professor 9, Donnybrook*. Both professors, while supporters of EDI initiatives are worried that EDI efforts run the risk of aggravating their colleagues and are potentially concerned about becoming seen as outsiders within their GEP community due to their support of EDI initiatives.

Using Bourdieu's theories to frame these results, I would argue that gender informs the habitus of engineers, and masculinist norms [22, 33] that pervade engineering environments, place women at a disadvantage and make it more likely that they will experience chilliness within an engineering environment and dissonance between their values and those reflected in their engineering environment and culture. This paper adds a new perspective to the literature that examines "chilliness" in engineering by applying the concept of split habitus in that it examines women in GEPs who are at a different life stage than undergrads.

Compared to undergraduates, women in GEPs are closer to grant application processes, have a higher investment in their academic career due to the time and effort they have already expended and, as they are older, organizational norms concerning becoming a parent or being perceived as a leader may be of greater importance to them. These factors played into the experiences of women participants in this study and made it more likely that they were better positioned than women in undergraduate programs to observe the pushback on EDI initiatives, the performative nature of peers' compliance with EDI, and how male norms shape conceptions of success and leadership. Thus, while all participants expressed high levels of commitment and interest in their work, "chilly" experiences caused them to feel set apart from their peers and experience

dissonance between what they valued, and what it appeared their community valued, which would reflect Bourdieu's notion of the split habitus.

In summary, to answer research question number two, women participants in GEPs did experience chilliness in various forms. Participants felt excluded by the language and behavior of male peers and were concerned that parental leave or being a parent was problematic from an institutional perspective, often creating perceived barriers to professional success. They also experienced backlash to EDI initiatives on an individual and organizational level. These experiences contributed to women's sense of belonging to the community being lessened. However, most women participants, despite the dissonance they experienced, expected to carry on in their roles due to their interest, enjoyment, and investment in the work that they did. It should also be noted that participants who were men also reported negative experiences resulting from backlash to EDI initiatives that weakened their sense of belonging and diminished their ability to relate to and work with peers.

Recommendations and Conclusions

This section presents the various recommendations provided by participants in their interviews to increase the proportion of women within GEPs and concludes by summarizing the implications of the findings in this paper and outlining future directions for additional research.

Five faculty members noted that leadership engagement in EDI initiatives in general, and gender equity in particular, were critical to ensuring efforts to increase the proportion of women in GEPs were successful and backlash to EDI initiatives was addressed. Professor 5 stated strong leadership from their dean's office and other senior departmental members on EDI issues gave her and her colleagues hope for the future. Professor 3 believed that top leadership involvement was critical to ensure EDI work was not performative.

> We want to have a good conscience by doing all of this [EDI work] … But in reality, what do we do in action? …that's why I think it has to come from the top. The academic system needs to do something if they want to, to really do this. *Professor 3, Benmiller.*

Professor 6 cautioned that the administration also needs to be aware of potential unintended consequences of EDI policy noting "We have university policy that there must be a woman in every committee. And so, if you're the only woman in the department, boy you have some administrative overload."

Three professors, 1, 4, and 6, were concerned that many undergraduate students, particularly underrepresented students such as women, were unaware of the opportunities graduate degrees created or the available. These professors spoke to undergraduates in their senior years and held information sessions, but all believed their institution could provide more information and coaching to undergraduates from underrepresented groups to encourage and support them in applying to GEPs.

Professor 8 believed that "mentorship… is probably the biggest barrier for women and minorities… people… gravitate towards helping people they feel are similar to them… this

unconscious bias of spending more time with people that are similar to yourself... it creates this barrier to [accessing] mentorship". Professor 5 also believed that mentorship was important, but noted that women needed to be supported, at both the faculty and the student level, once they entered GEPs, that hiring women was a great goal, but facilitating their success should be another.

As discussed above, faculty and students perceived that their institutional cultures were not responsive to family responsibilities with institutions problematizing being pregnant or a mother and supervisors and peers behaving as if family responsibilities did not exist for anyone in GEPs. Professor 8 recommended that parental leave policies are understood and supported by administrators and support is provided to ease the transition back from leave. I would argue that problematizing or ignoring individuals' family responsibilities may be counterproductive and potentially alienate individuals who are parents, considering starting a family, or believe that parenthood is not incompatible with being a successful engineer. Providing institutional support to individuals when they choose to take parental leave is not a trivial undertaking, but it has been associated with retaining valuable employees [46].

A future direction for research would be to examine why part-time student numbers have stayed flat, while the growth in the number of full-time students has increased significantly. Part-time programs could be a pathway that widens access pathways for students who must continue working full-time while studying, and also for students looking to better balance their family responsibilities with graduate studies while supporting life-long learning for all engineers.

Despite the limitations of this research noted above, from a quantitative perspective this paper had added to our knowledge of longitudinal, gendered graduation patterns in GEPs. While we knew that the proportion of women in Canadian GEPs was less than in other STEM graduate programs, it was not known that the change in the proportion of women in GEPs was only three percentage points over 2000-2019, that the proportion of women was held constant across various populations and that the proportion of part-time students in GEPs over the period dropped from 24% to 8%. From a qualitative perspective, this paper has added to our knowledge of how chilliness manifests for women in GEPs, and the needs and concerns of graduate engineering students differ from those in undergraduate programs. At a practical level, this paper provides recommendations as to how the proportion of women could be increased in Canadian GEPs that provide practitioners with various options and alternatives to consider and potentially apply to their GEPs.

Appendix 1: Demographics of Participants

Demographics Gathered in Faculty Interviews

Categories	Count	Donnybrook	Benmiller
Women	6	2	4
Men	4	3	1
Racialized Women	2	1	1
Racialized Men	2	1	1
Less than 10 years	4	2	2
10 years of more	6	3	3
Total Faculty	10	5	5

Demographics Gathered in Student interviews

Demographic Data	Category	Benmiller	Donnybrook	Total
Gender	Women	5	5	10
	Men	5	5	10
	CIS	9	8	17
	non-CIS	1	2	3
Level of Study	MEng	5		5
	MASc	3	3	6
	PhD	2	7	9
Visa Status	Domestic	3	6	9
	International	7	4	11
High School	Public	7	8	15
	Private	3	2	5
Parents' Highest Level of Education	High School	6	1	7
	Bachelor	11	12	23
	Master's		5	5
	Phd	1		1
	N/A	2	2	4
Engineer in the Family?	Yes	7	4	11
	No	3	6	9
Socio-Economic Status	Working	2	1	3
	Middle	6	6	12
	Upper Middle	2	3	5
Race	Racialised	9	4	13

Appendix II: Government Benefits Paid and Time Allowed during Maternal and Parental Benefits Leave

Maternity and parental benefits overview

Benefit name	Maximum weeks	Benefit rate	Weekly max
Maternity* (for the person giving birth)	up to 15 weeks	55%	up to $695
Standard parental	up to 40 weeks can be shared between parents, but one parent cannot receive more than 35 weeks of standard benefits	55%	up to $695
Extended parental	up to 69 weeks can be shared between parents, but one parent cannot receive more than 61 weeks of extended benefits	33%	up to $417

n.b. These are federal payments made by the Canadian government to individuals on maternal or parental leave. Large companies in Canada often opt to "top-up" salaries for individuals on maternity or parental leave bringing salaries up to 80% of pre-leave salary. Please see the link below for additional information on government regulations regarding maternal and parental leave in Canada.

https://www.canada.ca/en/services/benefits/ei/ei-maternity-parental.html