Decoding Determinants: An Intersectional Exploration of Students' Decision-Making for Graduate Engineering Education

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Abstract

Over the ten-year period from 2011 to 2020, a major research-based Canadian university experienced a 5% increase in female enrollment in postgraduate engineering programs, exceeding the national average. Nonetheless, an intriguing discrepancy emerges when juxtaposed with the 15% surge in female undergraduate enrollment during the same period. Such a disparity underscores a significant potential for bolstering women's transition from undergraduate to graduate studies. Capitalizing on this latent pool of female undergraduates could further propel gender equity in the university's engineering program.

This paper delves into the demographic determinants influencing students' inclination towards graduate studies, assessing the nuances of gender, citizenship status, disability, race, sexual orientation, and family education. The presented findings emanate from the fourth phase of an extensive multiphase mixed-method research project. The project seeks to elucidate the impediments that underrepresented students, particularly women, face in pursuing graduate engineering degrees and the potential solutions to overcome those barriers.

Our methodology in this phase encompassed a comprehensive mixed-method survey, garnering responses from over 600 undergraduate and graduate engineering students within the Faculty of Engineering. Preliminary analyses revealed that the decision to pursue graduate studies is influenced by intersectional identity variables.

In the sphere of engineering education, the pursuit of diversity, inclusion, and equity has long been recognized as imperative, yet the representation and participation of women and minority groups in graduate degrees remains a pressing concern. A significant hindrance has been Canada's erstwhile data collection methodologies, which have not robustly and systematically captured granular demographic information about students' race, disability, sexual orientation, and familial backgrounds. This has historically stymied a detailed intersectional analysis of engineering students' experiences and the factors driving their post-undergraduate academic choices. This research facilitates a more discerning examination of intersectional influences by meticulously incorporating these crucial demographic variables into our comprehensive survey and analyzing the responses from a substantial cohort of engineering students. The results enrich the academic literature on equitable engineering graduate recruitment and retention, adding layers of complexity and depth.

Keywords: graduate Engineering studies, women in engineering, underrepresentation in engineering, decision-making factors, EDI.

Introduction

In the evolving landscape of higher education, the decision to pursue graduate studies, especially within the engineering disciplines, is influenced by a complex matrix of factors that extend beyond academic interests and career aspirations. This complexity is magnified when viewed through the lens of diversity, inclusion, and equity, particularly in the scarcity of robust and systematic demographic data collection systems in Canadian higher education. Despite notable strides toward enhancing parity and inclusion in undergraduate enrollments, a persistent gap remains in the transition to graduate studies, particularly among women, students of color, those with disabilities, and individuals from non-traditional educational backgrounds.

This article investigates the multifaceted decision-making process for students contemplating graduate engineering programs, underscoring the intersectionality of gender, race, citizenship, and other demographic factors. Understanding how various demographic factors intersect to impact the decision-making process is essential for developing more effective recruitment strategies and supportive policies. Specifically, the study seeks to answer this research question: How do demographic factors such as gender, sexual orientation, race, citizenship status, family education, and educational background influence the decision to pursue graduate engineering education?

The methodology employed in this study integrates a detailed survey approach, conducted within the Faculty of Engineering at a prominent research-based Canadian university. In this paper, the Faculty of Engineering (or the Faculty with the capital F) refers to the academic division within the researched university that encompasses all the departments, institutions, and centers involved in engineering studies. The survey, as part of a broader multi-phase mixed-method study, aimed at examining the roles of identity and familial background on students' intentions towards graduate engineering studies, as well as investigating the lived experiences of engineering graduate and undergraduate students at the Faculty across their intersectional identity factors. This paper specifically draws from the survey's initial segment, including data on participants' demographics, educational backgrounds, undergraduate participants' future graduate study plans, and graduate participants' re-evaluation of their decisions to continue graduate studies. Over 600 students participated, with 413 responses analyzed quantitatively, focusing on the first 26 questions to assess decision influences. Statistical analyses, including Pearson's Chi-Squared Test and logistic regression, were applied to pinpoint significant trends, underpinning the research with a strong reliability measure, evidenced by a Cronbach's alpha value over 0.95, ensuring a robust examination of the factors influencing graduate engineering education decisions.

Following this introduction, the article is organized into several key sections: a literature review that situates the study within the broader research context, a detailed description of the methodology, a presentation of the research findings, and a discussion of the implications of these findings for policy, practice, and future research. The conclusion will synthesize the study's contributions to the field and suggest pathways forward.

The findings of this study are expected to contribute to the field of diversity, inclusion, and equity in engineering graduate degrees by highlighting the interplay of demographic factors influencing students' decision-making processes. The study's outcomes and the survey dataset will serve as a foundation for future research directions, providing insights into the diverse

motivations and barriers faced by potential graduate students, based on their intersectional identity factors. The larger study aims to inform policymakers, educators, and institutions in their efforts to foster a more inclusive and equitable academic environment in engineering.

Review of the literature

The scarcity of women in graduate engineering programs poses a critical barrier to leveraging a diverse talent pool for addressing societal challenges. While the exploration of Equity, Diversity, and Inclusion (EDI) in undergraduate engineering has been extensive, research into graduate-level enrollment, particularly in engineering, is not as widespread [1], [2], [3]. Studies are increasingly focusing on what influences undergraduates' choices to pursue graduate studies and their success. Posselt [4] critically examines the complexities of the admissions process and its implications for diversity in core academic disciplines. However, the number of studies specifically targeting engineering, and even more so, those analyzing gender disparities in graduate applications and admissions, remains limited [5], [6].

Several deterrents to applying for engineering graduate programs have been identified, irrespective of identity factors. A key factor challenging students' and potential returnees' decision to pursue graduate degrees in engineering is the lack of adequate knowledge and clear understanding of the application and admission processes [5], [9], available financial resources [8], and perceived challenges in successfully completing graduate studies [5], [7]. Self-doubt regarding graduate study success, particularly for women in engineering, has been a noted discouragement [2], [6]. Wofford [7] suggests introducing the concept of graduate education early in undergraduate programs and establishing institutional frameworks to bolster students' self-confidence, focusing on women and other minority groups. In addition, the role of past experiences and academic achievements in shaping undergraduates' decisions to pursue advanced studies is also significant. Ro et al. [8] found that leadership experiences and mathematical skills positively influence students' intentions to seek graduate degrees, while involvement in non-engineering community services inclined them towards non-engineering fields.

The availability of resources, opportunities, and support systems is crucial in shaping undergraduates' decisions to apply for graduate studies. For instance, engaging in undergraduate research experiences positively impacts students' attitudes toward graduate studies [8], [9], [10], [11], [12]. Thus, promoting research opportunities at the undergraduate level can increase the likelihood of students applying for and succeeding in graduate programs [13]. Additionally, the absence of mentorship and support networks, a challenge more pronounced for women and other underrepresented groups, can lead to feelings of isolation and lower confidence, influencing their decisions against pursuing graduate degrees. Positive faculty members’ advisement and interactions with graduate students have been correlated with continued academic progression [6].

Institutional factors also play a pivotal role in shaping female students' experiences in engineering and their decisions to pursue graduate studies. These include family-friendly policies [16], [18], and gender-inclusive admission processes [2], [17]. Furthermore, expanding admission criteria beyond a strict engineering background can diversify the applicant pool [7]. As another institutional factor, inclusive engineering curricula and teaching methods that support

racial, gender, legal status, ability, and other differences can help to avoid alienating underrepresented groups from the field [17], [18], [19].

Finally, the lack of female role models in engineering faculties and leadership positions can perpetuate cultural stereotypes, affecting women's decisions to continue in the field or pursue advanced degrees [14], [15], [20]. Stereotypical perceptions often lead to discouraging attitudes from family and peers, impacting women's choices in engineering [21], [22].

This study aims to build upon existing research and delve deeply into the various demographic factors that sway students' decisions to pursue graduate studies, with a particular focus on gender, in intersection with indigeneity, disability, race, sexual orientation, and family educational background. It meticulously examines how these intersectional factors uniquely impact students' choices in engineering graduate studies. By exploring these dimensions, the study aims to offer a comprehensive understanding of the decision-making process for graduate studies among diverse student populations, contributing significantly to the discourse on equity and inclusivity in engineering education, focusing on the predominant challenges that underrepresented engineering students, particularly women, encounter in graduate education.

Data and Methodology

- Data collection and the research instrument

This study aimed to gain insight into the factors influencing students' decisions to pursue graduate studies in engineering. We conducted a survey in the Faculty of Engineering at a research-based university in Ontario, Canada. The survey sought correlations between students' intersectional identity factors and family background, their perceptions of the Faculty of Engineering’s resources and support systems, their lived experiences of discrimination, inclusion, equity, and equality, and their decisions to (re)consider graduate degrees. The survey was created and administered through REDCap, a secure online platform designed for creating and managing databases and surveys on the web. Ethics approval had been sought from and granted by the Research Ethics Board at the targeted university.

Six hundred students from undergraduate and graduate engineering studies at the university responded to the survey. After filtering out 187 incomplete or invalid responses, the data was restructured to include 413 unique participants. The reduced population size was still sufficiently large to proceed with the statistical analysis. The participants formed about 7% of all the students invited to respond to the survey. The survey started by providing a brief overview of the larger study and the survey and asked for participants' consent.

The variables used in the survey were validated in two ways. First, the questions were designed based on the factors that previous studies have examined regarding the challenges that minority students, particularly women, faced in STEM fields, the alternatives to address those challenges, and the factors that undergraduate students employ to decide about graduate studies. Second, this study is part of a larger research agenda on building pathways for underrepresented minority populations into engineering graduate degrees. In the previous phases of the larger study, we conducted interviews with faculty members, staff, and students at the targeted university. The

analysis of these interviews was used to inform the survey questions. The survey's validity was strengthened further through interviews with five students to identify any issues with the survey questions. Four experts in survey design and EDI in engineering reviewed the survey and provided feedback on survey questions regarding their relevance, wording, and inclusion. In addition, we piloted the survey, and over 50 students from the researched university responded and provided feedback on the pilot version. The final survey was administered in February and March 2023. It was distributed to all students at the Faculty of Engineering through the Undergraduate and Graduate Dean's offices, students' affinity groups, the Communication Office, the Faculty social media and newsletter, and informal students' social media channels. For this study, we only worked with independent variables reflecting students' demographic factors, examining how these factors could have influenced their decision-making process regarding graduate studies. Table 1 shows the variables used in this paper.

- Participant demographics

Table 2 provides a comprehensive analysis of the demographic profile of the student respondents. A significant portion of the survey participants identified as female (n=249, 60.5%), heterosexual (n=318, 77%), White (n=177, 39.6%), or East Asian (n=103, 23%). A majority of the respondents were either Canadian citizens or permanent residents, comprising 70.5% of the total (n=291). A smaller segment, 8.47% (n=35), indicated they had a disability, with multiple disabilities reported in some cases. Notably, 63.2% of the respondents (n=261) came from families where at least one member had graduated from an engineering program.

For statistical analysis, we devised a novel gender variable, which was constructed based on participants' self-reported gender and sexual orientation. This variable classifies participants into three categories: Women (comprising those with a self-identified Cis-Woman gender and Heterosexual orientation), Men (constituted by individuals identifying as Cis-Man gender and Heterosexual orientation), and 2SLGBTQ+ (encompassing all other combinations of gender and sexual orientation). This categorization ensures statistical robustness by addressing the issue of insufficient sample sizes within certain gender and sexual orientation groups, which might otherwise compromise the validity of the quantitative analysis. Nonetheless, it is important to note that for specific correlation analyses and regression models, we reverted to the original, disaggregated gender and sexual orientation groups to maintain analytical precision.

- Data analysis

In this study, we explored the demographic determinants that drove undergraduate participants to pursue engineering graduate degrees. We also investigated the correlation of these determinants with retrospective choices of current graduate students, assessing whether, with their acquired experiences and insights into graduate life, they would opt to reapply for their engineering graduate programs when revisiting their initial decision. As shown in Table 1 we worked with various identity factors, to explore potential correlations with these decisions. The reliability of these independent variables was confirmed through a high Cronbach's alpha value (exceeding 0.95), underscoring the robustness of our measurement methods. Our survey utilized a Likert scale ranging from 1 to 6 for each item. To analyze the survey data collected from over 400 engineering students at the researched university in Ontario, Canada, we used the software

Rstudio, Version 4.2.1. We examined how students' decisions regarding engineering graduate degrees varied based on gender and sexual orientation, race, citizenship status, disability status, origin of bachelor's degree for graduate participants, year of study, field of study, and family education. We ran a cross-tabulation with Pearson's Chi-Squared Tests to examine whether either of the abovementioned factors correlates with respondents' choices regarding engineering graduate degrees. We also tested for the intersectional correlations of multiple demographic factors, such as gender and citizenship status, gender and family education, and gender and year of study. Appendix A shows the results of all cross-tabulations.

Table 1: Definition of variables used in the paper

Independent Variables	**Definition**
Level of study	Undergraduate, Research-based master's (MASc), Course-based master, Ph.D.
Program of study	Chemical, Civil, Computer, Electrical, Industrial, Material, Mechanical, Mineral, Engineering Science, Biomedical, Aerospace, Interdisciplinary and Leadership in Engineering, Other
Year of study.	1, 2, 3, 4, 5^{+}
Undergraduate origin	This question applied only to the graduate respondents
Gender	Woman, Man, Trans-woman, Trans-man, Non-binary, Two-Spirited, Prefer to self-describe, Prefer not to answer
Sexual orientation	Heterosexual, Homosexual, Bisexual, Two-Spirited, Prefer to self-describe, Prefer not to answer
Race	Black, East Asian, Hispanic, Indigenous, Middle Eastern and West Asian, South Asian, South-East Asian, White or Caucasian, Other racialized minority groups, Prefer not to answer
Disability status	No disability, ADHD, Autism, Chronic health condition, Concussion, Learning disability, Mental health condition, Mobility disability, Sensory disability, Temporary disability/injury, Not listed, Prefer not to answer
Citizenship status	Canadian Citizen, Permanent resident of Canada, International student, Protected person in Canada, Not listed, I prefer not to answer
Parents or siblings' education in engineering	If at least one of their parents or siblings have an engineering degree or studies in engineering
Dependant Variables	**Choices**
I am going to apply/have applied to a graduate program (For undergraduate respondents)	Yes/No.
I plan to pursue my upcoming graduate degree: (For undergraduate respondents)	*In an engineering field at our university. *In an engineering field at another university. *In a non-engineering field.
I do not want to pursue a graduate degree because (choose as many as apply): (For undergraduate respondents)	*I want to start working in an engineering field with my undergraduate degree. *I want to work in non-engineering fields. *I may apply in the future after gaining some work experience. *I have family priorities (getting married/ having a child/ taking care of family members). *Graduate school is a more challenging version of undergraduate studies. *My grades are too low for graduate studies admissions. *I will not get accepted if I apply to an engineering graduate program. *I am not interested in this field anymore. *Other reasons.
If I were to apply for graduate studies again, I would (choose as many as apply): (for graduate respondents)	*Choose the same university. *Choose the same field. *Not apply for a graduate degree anymore. *Choose a different university. *Choose a different field of study outside engineering.

Table 2: Participants' demographic profile

Study level	Undergraduate	Graduate			
		MASc	MENG	PhD	Total Graduate
Count	165	80	87	81	248
Percentage	39.95	19.37	21.06	19.61	60.04

Undergraduate origine	N/A	Researched University	Elsewhere
Count		125	123
Percentage		50.4	49.6

Year of study	UG1	UG2	UG3	UG4	UG5	G1	G2	G3	G4	G5
Count	13	27	53	58	14	84	85	43	20	16
Percentage	7.88	16.36	32.12	35.15	8.5	33.87	34.27	17.34	8.06	6.45

Gender	Woman	Man	Trans-woman	Trans-man	Non-binary	Two-spirited	Other
Count	249	140	4	3	8	1	9
Percentage	60.14	33.81	0.96	0.72	1.93	0.24	2.17

Sexual Orientation	Heterosexual	Homosexual	Bisexual	Two-spirited	Other
Count	318	20	39	1	38
Percentage	76.44	4.80	9.37	0.24	9.13

Gender/Sexual orientation Merged	Women (Heterosexual Cis-Women)	Men (Heterosexual Cis-Men)	2SLGBTQ+
Count	197	119	94
Percentage	47.47	28.67	22.65

Race	Black	East Asian	Other URM						White	URM
			Hispanic	Indigenous	Middle Eastern	South Asian	South-east Asian	Other URM[4]		
Count	12	103	27	4	44	46	9	12	177	257
Percentage	2.68	23.04	6.04	0.89	9.84	10.29	2.01	2.68	39.6	60.4

Citizenship Status	Domestic			International		
	Canadian citizen	Permanent resident	Total	Visa	Protected person	Total
Count	243	48	291	114	2	116
Percentage	58.84	11.62	70.46	27.60	0.49	28.08

Disability Status	Yes									No
	ADHD[1]	ASD[2]	Chronic	Concussion	LD[3]	Mental health	Mobility disability	Sensory disability	Temporary disability	
Count	8	6	6	1	6	13	1	0	1	361
Percentage	1.9	1.43	1.43	0.24	1.43	3.09	0.24	0	0.24	85.95

Department	Chemical	Civil	Computer	Electrical	Industrial	Material	Mechanical	Mineral	Eng. Science	Biomedical	Aerospace	Other
Count	65	47	28	48	30	39	33	2	78	22	18	3
Percentage	15.74	11.38	6.78	11.62	7.26	9.44	7.99	0.48	18.88	5.32	4.35	0.72

Family member engineer	Yes			No		
	Undergraduate	Graduate	Total	Undergraduate	Graduate	Total
Count	103	158	261	62	90	152
Percentage	62.42	63.70	63.19	37.57	36.29	36.80

[1] Attention-deficit hyperactivity disorder. [2] Autism Spectrum Disorder. [3] Learning Disability. [4] Other Underrepresented Racialized Minority Students.

- Limitations

Surveys, while a popular tool for data collection, have several limitations. First, survey data might not be able to represent the population to which they are distributed. There is also the risk of sample contamination by biased respondents. These issues challenge the generalizability of survey findings. Because of limitations in collecting students' demographic data in Canada and the researched university, determining if our data was representative of engineering students is challenging. We took two approaches to address this challenge [23]. First, we compared our sample with other surveys that the Engineering Faculty has been collecting from graduate and undergraduate students in the last few years. Two, we kept the survey open for a whole month and reached out to graduate and undergraduate students through various official and informal channels to ensure that every engineering student at the university received the survey link. In addition, inherent in these data are biases typical of all social science survey research. These include the inclination towards socially desirable responses, the accuracy of memory recall, and the readiness to engage in the survey. Such biases could potentially skew the absolute figures of our analysis in a certain direction. However, these biases are less likely to significantly affect comparative analyses and correlations.

Findings

We start this section with descriptive findings and then move to the models we used to understand the correlation between demographic factors and students' decisions regarding graduate studies (both for undergraduates considering future paths and graduates reflecting on their past choices). As shown in Table 1, the survey asked undergraduate students if they were going to or had applied for a graduate program. Those students who responded yes to this question were asked if they planned to pursue their graduate studies in an engineering field at the researched university, in an engineering field at another university, or in a non-engineering field. Those who did not plan to apply for graduate degrees, were given the option to select the reasons behind their decision (check Table 1 to see the options). The graduate students were asked what they would have done if they could go back in time and revise their decisions about graduate studies: Would they choose the same university, the same field, a non-engineering graduate program, or they would not apply for a graduate degree anymore.

Figure 1 shows the distribution of undergraduate participants' decisions regarding graduate studies. Based on survey data 43.6% of undergraduate respondents did not plan to pursue graduate studies in engineering (either did not plan to apply for graduate studies at all or planned to continue non-engineering graduate fields). 43.0% of undergraduate students considered the same institution and 32.7% of them considered other institutions for their engineering graduate studies (25 students considered both options). Therefore, at least 57% of students considered leaving their Faculty after completing their undergraduate programs.

We asked about the motivations of the 35.2% of undergraduates who chose not to pursue graduate studies. The majority (55.6%) intended to enter the engineering workforce directly after graduation. Additionally, a notable number of these students expressed concerns about their eligibility for graduate programs, citing reasons such as perceived low grades, the anticipated

rigor of graduate studies compared to undergraduate courses, and doubts about meeting the qualifications for graduate programs. Our previous research, based on mining students' administrative data, confirms that grade-based academic performance is one of the key contributors to undergraduate students' intention to apply (or not) for graduate degrees [3].

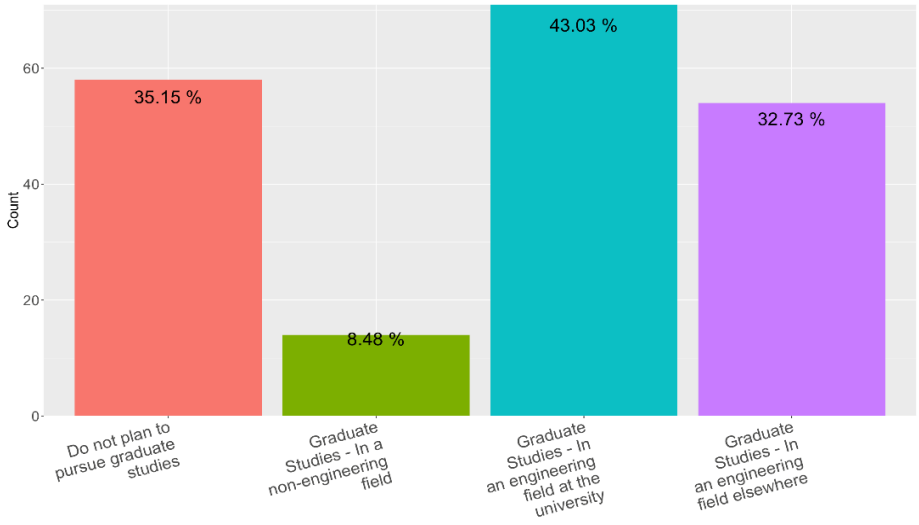

Figure 1: Distribution of undergraduate participants' decisions to pursue graduate studies

- Gender

Breaking down the decision and reasons for not pursuing graduate studies by gender, provides nuanced insights into gender differences. 47.6% of women and 48.9% of 2SLGBTQ+ did not plan to pursue engineering graduate degrees, while this percentage is 28.2% for men. Based on the analysis of the reasons that undergraduate participants selected for not applying for graduate studies, men seem most confident about their job prospects with an undergraduate degree, with 72.7% of them intending to work in their field after completing their undergraduate program, compared with 59.5% of women and 40.0% of 2SLGBTQ+group (

Figure 2). The 2SLGBTQ+group is notably more likely to consider working in a non-engineering field (25.0%) compared to women (10.8%) and men (0%). The 2SLGBTQ+group is most concerned with low grades. Higher percentages of women and 2SLGBTQ+ groups also did not think they would have been accepted to engineering graduate programs, compared with their male counterparts. 25% of 2SLGBTQ+ groups were not interested in their engineering field anymore, followed by 8.1% of women. None of the men selected this option.

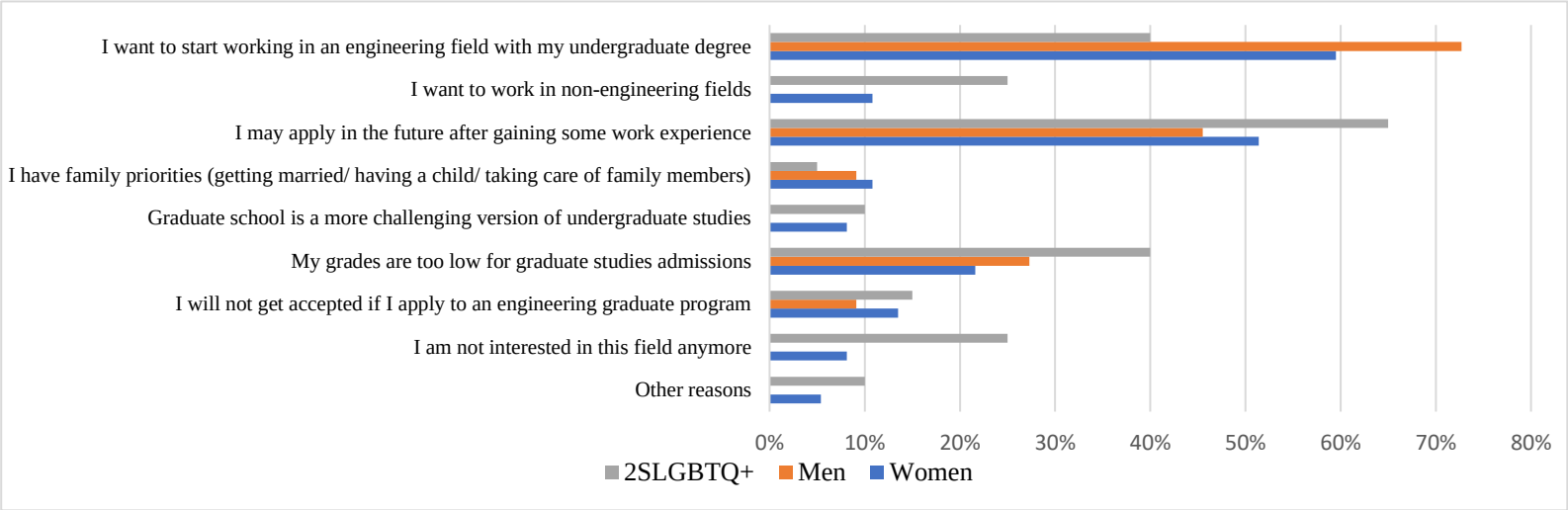

Figure 2: Gender-wise distribution of factors influencing undergraduate participants' decisions against pursuing graduate studies

The breakdown of the graduate participants' retrospective choices and their reevaluation of their decision to pursue graduate studies reveals important insights about their lived experiences as graduate students. 43.9% of the graduate participants (n=109) would choose the same graduate program at the same university. Interestingly, a significant portion of graduate students chose not to pursue engineering graduate degrees when revisiting their decisions. As shown in Figure 3, given the chance 31.4% of 2SLGBTQ+ graduate respondents would not enroll in engineering graduate studies if they could reconsider their decision. The percentage is significantly lower for female and male graduate respondents. The stacked columns do not necessarily total 100%, because we only considered the responses that had selected both options of 'same field' and 'same university', and 'same field' and 'different university'. We did not count the responses that had selected only one of 'same university' or 'same field', because we could not categorize those responses based on the logic used in Figure 3.

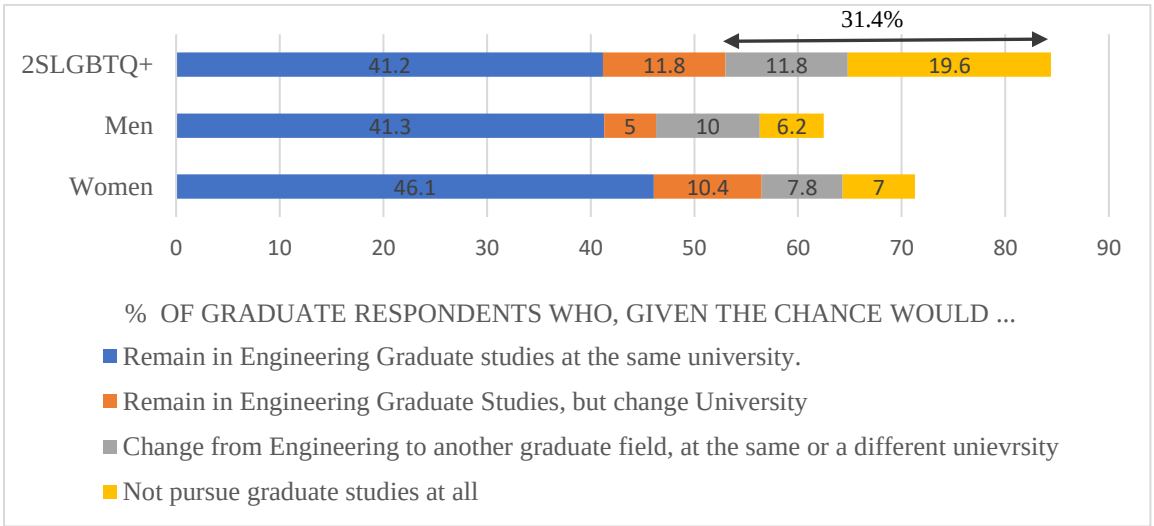

Figure 3: Gender-wise distribution of graduate participants' retrospective choices

Figure 4 considers all responses. It shows that more than 58% of the 2SLGBTQ+ students would not have stayed at the researched university, compared with about 33% of women and men. This large group would have either not applied for engineering graduate degrees or chosen a different university for their graduate studies.

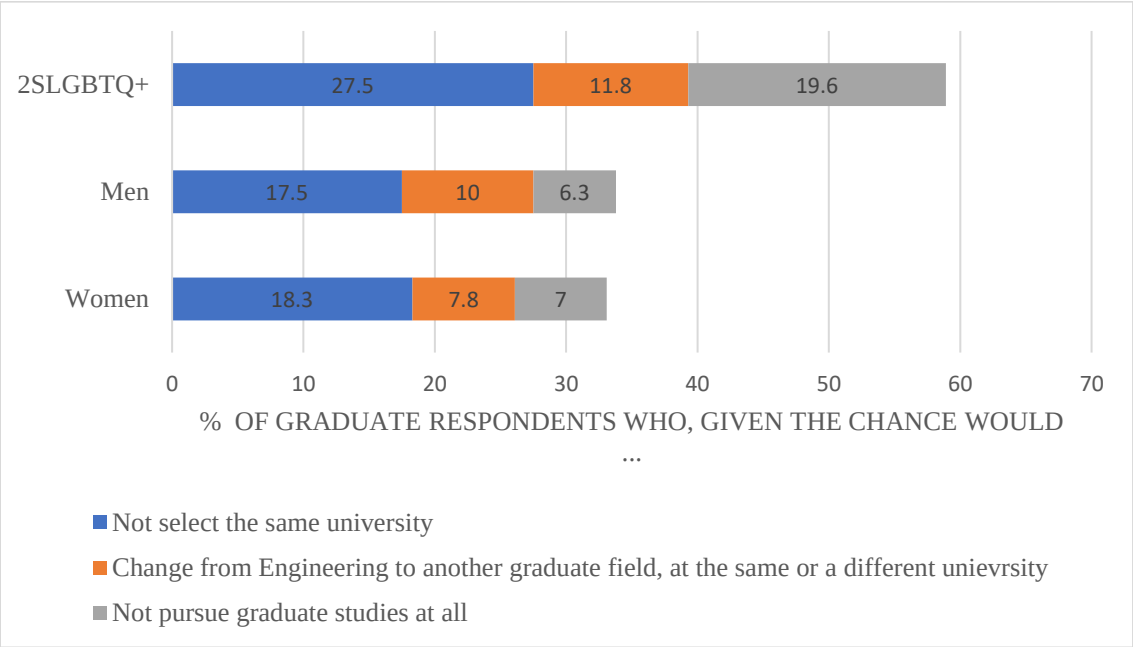

Figure 4: Gender-wise distribution of graduate participants' decisions: Leaving the researched university

- Family education

The survey data shows that 62.4 % of undergraduate and 63.7 % of graduate respondents had at least a family member with an engineering degree. Therefore, having a family member with an engineering degree has facilitated students' decision to choose engineering as their undergraduate field of study or to pursue advanced degrees. However, the Chi-Square Tests for association showed no significant association between family education and the participant's decision to (re)pursue graduate engineering studies, at both undergraduate and graduate levels (Appendix A). Therefore, once students selected their field of study, family education had no influence on their decision-making process regarding the pursuit of graduate studies.

- Citizenship status

The survey data reveals that both domestic and international undergraduate students show a strong interest in pursuing engineering graduate degrees. The significance level for undergraduates suggests a meaningful correlation between citizenship status and their decisions. For graduates, the correlation is not significant, indicating that citizenship plays a more crucial role in undergraduate decisions than in graduate retrospective choices.

A significant majority of domestic undergraduates (71.11%) are considering engineering graduate studies, either at their current university or elsewhere. International undergraduates demonstrate an even higher commitment to engineering, with 100% indicating interest in graduate studies in the field, suggesting many are considering multiple institutions and are highly committed to continuing their engineering education. In the graduate cohort, the patterns of retrospective choices are similar across citizenship lines. Just over half of both domestic (52.56%) and international (52.27%) graduate students would choose to reapply for an engineering graduate degree, with a slight preference for their current university. However, a notable minority in both groups, around 18%, would either switch fields or opt not to pursue graduate studies upon reflection.

We also investigated how intersectional factors of gender and citizenship influence engineering undergraduates contemplating their future academic paths and graduates reflecting on their past choices. The significance levels suggest that gender and citizenship together have a moderate correlation with educational decisions among engineering students. Among undergraduate participants, international men and women showed a stronger commitment to further engineering education, compared with their domestic and international 2SLGBTQ+ and domestic women. For graduate students, the pattern shifts slightly. International women show a relatively high propensity to reapply for engineering graduate degrees, with a total interest of 61.70%. Domestic and international 2SLGBTQ+ students and international men demonstrated a significant drop in their inclination to reapply for engineering graduate degrees.

- Race

The survey data reveals distinct trends in the educational choices of engineering students across different racial groups. As shown in Figure 5 An impressive 92.16% of East-Asian undergraduates expressed a preference for engineering graduate degrees, with 41.18% considering the same university and a notable 50.98% looking at different universities. 69.23% of White undergraduates planned to pursue such degrees, either at their current university (40%) or elsewhere (29.2%). This interest is slightly lower compared to other racialized groups, even though they also demonstrated significant interest, with 63.49% considering engineering graduate degrees, either at their current university (44.4%) or elsewhere (19%).

Among graduate students, these patterns persist but with varying degrees. 53.57% of white students are considering reapplying for engineering graduate degrees, which is lower than the 67.31% observed in East-Asian students, who show the highest propensity for continuing in engineering. Other racialized graduate students have a comparatively lower total of 44.79% who would remain in engineering graduate programs.

The data also reveals a strong correlation between race and educational decisions at the graduate level (significance level of 0.02), but not at the undergraduate level, suggesting that racial background becomes more influential in decision-making as students progress in their academic careers.

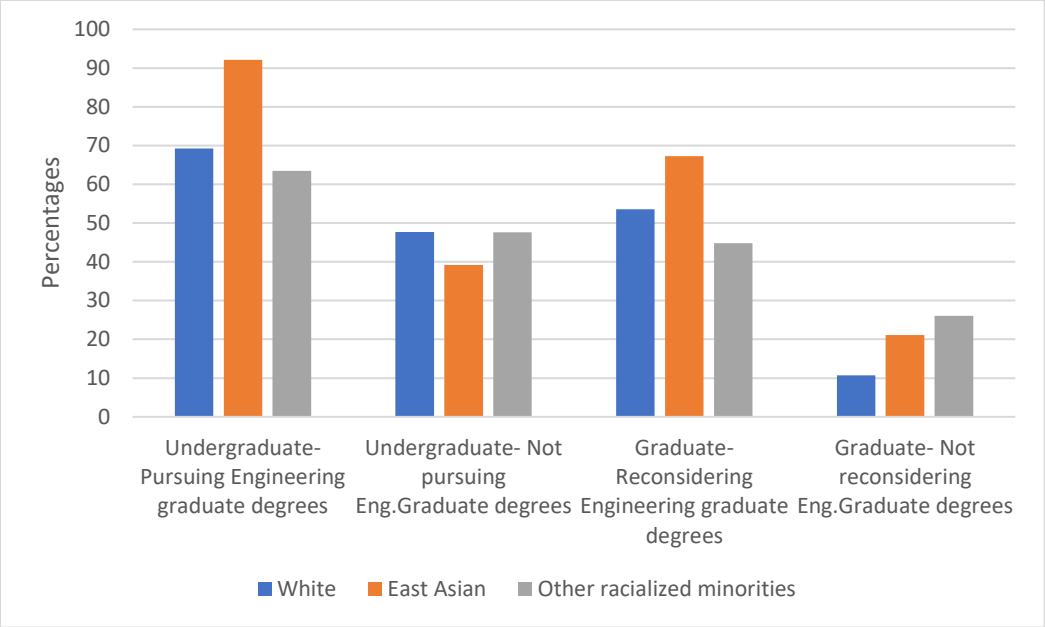

Figure 5: Students' decision to (re)pursue engineering graduate degrees based on race

The intersectional analysis across gender and race indicates that racialized men exhibited the highest interest among all groups, with 93.74% considering engineering graduate degrees, followed by white men and women. White 2SLGBTQ+ students showed the least interest; 77.8% of them indicated no desire to pursue engineering graduate degrees. Reflecting on graduate students' decisions, white men and women were more likely to consider different paths than engineering graduate degrees, while racialized 2SLGBTQ+ students were more likely to make the shift, given the chance. The significance levels (0.009 for undergraduates and 0.05 for graduates) indicate a strong correlation between the combined factors of race and gender with students' decisions to pursue graduate studies, more so at the undergraduate level.

- Year of Study

The survey data provides a detailed look into how the year of study is correlated with engineering students' decisions regarding graduate studies. First-year undergraduate students show the least inclination, with only 38.46% considering such degrees, either at their current university or elsewhere. This percentage steadily increases, peaking with fourth-year students, 82.76% of whom plan to pursue engineering graduate degrees, showcasing the highest commitment among all year groups. Interestingly, the interest slightly declines for students in their fifth year or beyond, indicating a potential saturation point or a shift in priorities when it takes more than four years for students to complete their undergraduate studies.

Graduate students' retrospective choices exhibit a different pattern, less influenced by the year of study. First-year graduate students, reflecting on their decisions, show a moderate inclination (59.52%) to reapply for engineering graduate degrees, with a significant drop in interest among students in their fifth year or beyond, where only 25% would make the same choice again.

- Disability, Engineering department, Bachelor alma mater

The survey data did not show any significant correlations between factors such as disability status, department, and bachelor alma mater, with the educational decisions of engineering students, both for undergraduates considering future paths and graduates reflecting on their past choices.

For students with disabilities, there's a slight variation in their inclination towards pursuing engineering graduate degrees, with 64.71% of undergraduates with disabilities considering such degrees, compared to 79.13% of those without disabilities. The significance levels indicate that disability status has a moderate correlation with undergraduate decisions (0.1), but the correlation with graduate decisions is not significant.

Departmental affiliation shows varied interest across different fields of study, with Electrical Engineering undergraduates showing the highest interest in pursuing engineering graduate degrees (93.34%), and Industrial Engineering students showing the least interest with 66.7% of them not planning to pursue engineering graduate studies, followed by Mechanical Engineering and Computer Engineering. Among graduate students, Aerospace Engineering students exhibit a high propensity to reapply for engineering graduate degrees (83.34%), while Engineering Science students show the least interest, with 34% of them not imagining the same path for themselves. These findings, however, do not demonstrate a significant correlation between departmental affiliation and the decision to pursue or reapply for engineering graduate degrees.

The bachelor alma mater of graduate students (whether they graduated from the researched university or another university) shows no significant correlation (0.63) with their retrospective choices regarding engineering graduate studies. This suggests that the undergraduate institution's prestige or familiarity does not significantly impact graduate students' decisions to continue in the same field or institution.

- Sources of information about graduate studies

We asked the participants about the channels through which they receive information about graduate programs in engineering. Figure 6 shows undergraduate participants’ responses. Survey data shows that women and 2SLGBTQ+ undergraduate students, predominantly receive information through informal discussions with friends, while men more frequently gain insights from involvement in undergraduate research projects, followed by their informal network channels. Interestingly, faculty members are one of the main sources of information only for men. Notably, a considerable percentage across all genders, particularly 2SLGBTQ+ students, followed by women, reported not having received enough information about graduate studies, indicating a potential area for universities to improve communication. The Graduate Office is the least utilized resource, especially among the 2SLGBTQ+group, who reported zero engagement. Overall, the data suggests diverse information channels for different gender identities with room for enhancing formal information dissemination.

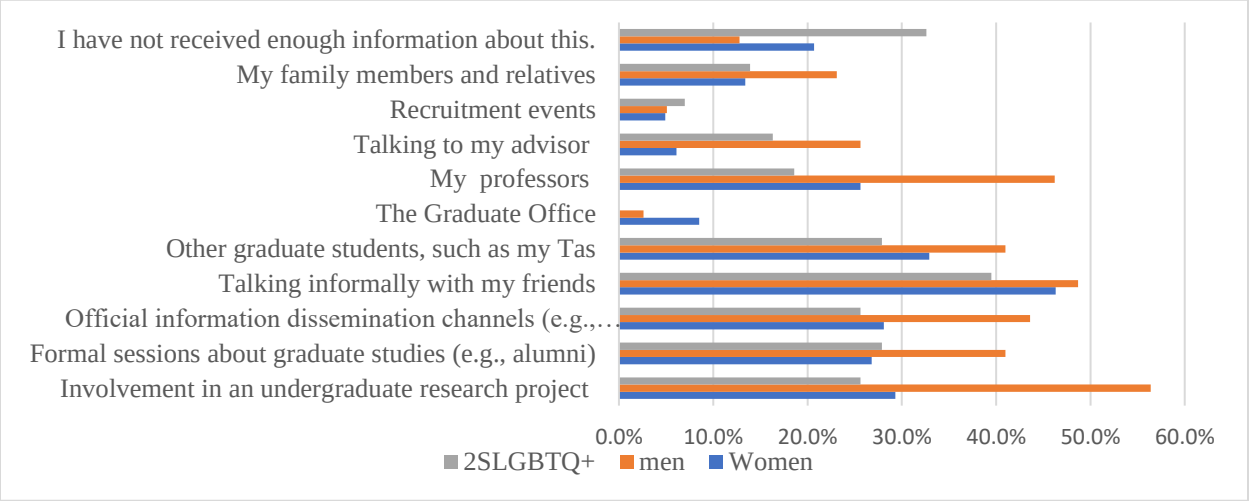

Figure 6: Gender-wise distribution of undergraduate participants' streams of receiving information regarding graduate studies

Discussion

Our study's findings offer valuable insights into the factors influencing students' decisions regarding engineering graduate studies. The data reveals a complex interplay of demographic, academic, and personal considerations shaping these choices. We discuss these factors separately for undergraduate and graduate students.

- Undergraduate students' decisions regarding engineering graduate studies

57% of the undergraduate participants planned to leave the Faculty of Engineering at the researched university after graduation, and 43% considered remaining in the same university. The public annual report by the researched university also indicates that 37% of full-time undergraduate students have moved to full-time graduate programs in 2022-2023 [24]. These numbers show that there is a large pool of potential graduate candidates that the Faculty is losing. A significant portion of undergraduate participants, 43.6%, also did not plan to pursue graduate studies in engineering. Gender differences were notable, with a higher percentage of women and 2SLGBTQ+ undergraduate participants opting out of engineering graduate studies compared to men. This disparity suggests underlying factors such as perceived barriers or lack of encouragement in pursuing advanced degrees in engineering for these groups. Undergraduate students' decision to not pursue graduate degrees was primarily driven by the desire to enter the workforce immediately after undergraduate studies, particularly for men. Concerns about academic readiness and eligibility for graduate programs were also prevalent, especially for 2SLGBTQ+ students followed by women, highlighting the need for more supportive academic environments and clearer communication about graduate program requirements, tailored to these groups.

While a family background in engineering appears to influence K-12 students' initial choice of engineering as an undergraduate field, it does not significantly impact their decision to pursue

graduate studies in engineering. This finding suggests that, once students embark on their engineering education, their decisions regarding advanced studies are more profoundly shaped by their personal experiences within their engineering departments rather than their family's educational background.

Citizenship plays a crucial role in undergraduate students' choices regarding engineering graduate studies. This is reflected in the significant correlation between their citizenship status and their decisions to pursue such studies. This trend is intriguing, especially when juxtaposed with our previous study [3], which highlighted that domestic undergraduate students are less inclined to apply for graduate studies in engineering despite having a higher chance of admission compared to international applicants. The strong appeal of engineering graduate programs among undergraduates, particularly international students, suggests that factors related to their background and perhaps the perceived value of engineering education in different cultural contexts influence their decisions. The intersectional data also reveal that international women and men, more than international 2SLGBTQ+ students exhibited a strong determination to pursue engineering graduate studies. Conversely, the varied interest levels among domestic students across different gender identities highlight the complex interplay of personal, cultural, and possibly institutional factors influencing their decisions to pursue or reconsider graduate studies in engineering.

Race does not play a significant role in influencing undergraduate students' decisions to pursue graduate studies. Notably, a moderately higher percentage of East Asian undergraduates, compared to White and other racial groups, planned to pursue graduate studies. The insignificance of race and the significance of citizenship status in undergraduate students' decisions suggests that the Faculty of Engineering's regulations and policies favor domestic applicants, whereas, these students face wider professional aspirations after their undergraduate studies. Therefore, they are less inclined to apply to engineering graduate programs, while standing higher admission chances. Cultural and societal influences, as well as more eliminated options after graduation, shape the educational choices of racialized international students. However, race and gender combined showed a strong intersectional correlation with students' decisions to pursue graduate studies. This suggests that these intersectional identities play a crucial role in shaping the aspirations of undergraduates to pursue graduate studies.

Undergraduate decisions are significantly influenced by their year of study, suggesting that as students progress in their academic journey and gain more academic and possibly practical experience, their interest in further engineering education grows.

The exploration of undergraduate students' decisions regarding engineering graduate studies highlights a multifaceted landscape of choices influenced by gender, family background, citizenship, and year of study. A significant portion of students, particularly women and 2SLGBTQ+ individuals, exhibit reluctance toward pursuing further engineering education. The critical role of citizenship and the nuanced impact of personal, cultural, and possibly institutional factors underscore the complexity of these decisions. Moreover, the progression through undergraduate studies appears to foster a growing interest in graduate education, suggesting a pivotal role for supportive academic environments and policies in facilitating these educational pathways.

- Graduate students' retrospective choices: Reevaluating the decision to pursue engineering graduate studies

The retrospective analysis of graduate students' decisions unveiled a critical perspective. While almost 44% would choose the same program and university, a considerable number expressed a preference for different paths if given the chance. This sentiment was particularly strong among 2SLGBTQ+ students, indicating possible dissatisfaction or unmet expectations within their current programs. The higher inclination of 2SLGBTQ+ students for alternative paths or universities underscores the importance of inclusive and supportive environments in graduate programs.

In our findings, it becomes evident that while family members with engineering backgrounds initially encourage students to embark on graduate studies in engineering, their actual experiences within these programs significantly shape their perspectives. Particularly the graduate students' inclination to consider different options appears to intensify with the duration of their time in the graduate program. This trend underscores the transformative impact of lived experiences in graduate studies, which can lead students to reevaluate and potentially alter their academic and professional trajectories, diverging from the initial expectations set by their family's influence.

Domestic and international graduate students exhibited a consistent pattern of reflection and reevaluation of their choices, irrespective of their citizenship status. This suggests that their lived experiences within the graduate programs play a more pivotal role than the students' background or citizenship, leading to a significant number of them considering different paths or even opting not to continue in their engineering graduate studies. The intersectional analysis shows that the 2SLGBTQ+ domestic and international graduate students are more likely to reconsider different paths than engineering graduate studies if they had the chance.

The influence of race on the reevaluation of educational decisions for graduate students is significant. White graduate students, in contrast to their undergraduate counterparts, are the least likely to reconsider their commitment to engineering graduate studies when given the opportunity. This shift in perspective from undergraduate to graduate levels indicates a complex evolution in how students perceive and engage with their academic and professional futures in engineering. The increased significance of racial background at the graduate level underscores the need for a deeper understanding of the diverse experiences and challenges faced by students from different racial groups. These insights are crucial for developing supportive and inclusive educational environments that cater to the varied needs and aspirations of graduate engineering students. The intersectional analysis of data also highlights the complex interplay of race and gender influencing the reflections of graduates on their decisions to continue in the engineering field.

The year of study has a less pronounced impact on graduate students' retrospective decisions, unlike undergraduate students' decisions. This suggests a more complex interplay of factors influencing graduate students' reflections on past choices. However, there is a decline in graduate students' inclination towards engineering graduate studies when reflecting on their past

choices, suggesting a reassessment of the value or appeal of further engineering studies as students advance in their graduate careers.

The graduate students' reflections on their choices to pursue engineering studies highlight a nuanced reevaluation of their educational and professional paths. Particularly for 2SLGBTQ+ students, there's a marked tendency to consider alternatives, underscoring the necessity for more inclusive and supportive academic environments. This introspection suggests that lived experiences within graduate programs significantly influence students' future decisions, potentially diverging from their initial motivations influenced by family or background.

Conclusion

The main motivation behind this project stemmed from the observation at a prominent Canadian university that, despite a notable rise in female undergraduate enrollment in engineering, the increase in female postgraduate engineering enrollment was not as substantial. This discrepancy highlighted a significant opportunity to encourage more women to advance from undergraduate to graduate studies in engineering, aiming to enhance gender equity within the university's engineering programs. The broader multi-phase project aims to uncover the challenges that marginalized groups, especially women, encounter in their pursuit of advanced degrees in engineering, and to identify effective strategies for addressing these obstacles.

This paper, by focusing on one of the phases of the project, informed by Faculty-wide survey data, examined the role of demographic characteristics and educational backgrounds in shaping decisions toward engineering graduate studies. Through a comprehensive analysis of survey data from a diverse group of participants in the Faculty of Engineering at the researched university, we aimed to understand how these various factors contribute to the decision-making process for students considering advanced engineering education. This investigation is pivotal for developing more inclusive and supportive educational environments, as it sheds light on the nuanced influences that guide students' paths toward graduate studies in engineering.

Even though most of the undergraduate students expressed interest in applying for engineering graduate degrees and most of the graduate students would have selected the same field upon reflecting on their choices, a notable portion of participants were reluctant to pursue graduate studies, particularly undergraduates. The study reveals a significant trend of undergraduates, especially women and 2SLGBTQ+ students, opting out of graduate engineering studies, due to immediate employment in the field, particularly for men, concerns about academic readiness and eligibility for graduate programs, particularly for 2SLGBTQ+ students and women, and working in non-engineering fields specifically for a large percentage of 2sLGBTQ+ students. This indicates a crucial loss of potential graduate candidates for the Faculty of Engineering, especially after accounting for those who planned to pursue their engineering graduate degrees at other universities. Comparably, a considerable number of graduate students, particularly from the 2SLGBTQ+ community, expressed the desire to consider alternative paths, indicating their dissatisfaction with their current programs.

Among the factors that we checked, the intersection of gender and race, and the intersection of gender and year of study significantly correlated with undergraduate students’ choices and

graduate students' reconsideration of their decisions. Citizenship and year of study emerged as crucial factors only in undergraduate participants' decision-making process. International men and women (not 2sLGBTQ+ students) demonstrated a strong inclination toward graduate studies. The significance of the year of study in undergraduate students' decision-making process also indicates evolving perspectives on graduate education as students' progress through their undergraduate journey. Family background in engineering was found to influence students' initial interest in choosing engineering as their field of study, however, it does not play a significant role in their decision to pursue engineering graduate studies.

Additionally, men reportedly utilize a wider array of formal and informal resources to gather information about graduate programs compared to women and 2SLGBTQ+students, who mostly rely on discussing the matter within their informal peer network. Men's broader access may contribute to their higher awareness and engagement in graduate studies. The disparity in information channels accessed by different gender identities underscores the need for universities to establish more inclusive communication strategies, ensuring all students have equal access to comprehensive information about graduate opportunities.

These findings suggest that students' decisions to advance their studies are more deeply influenced by their lived experiences and perceptions developed during their undergraduate or graduate education in the Faculty, rather than their identity factors. Even though intersectional insights underscore the complex interplay of identity, experience, and institutional factors in shaping pathways to graduate engineering education. For instance, the shift from familial influence to personal experiences within engineering programs, or the lack of strong significance between identity factors such as disability, race for undergraduate students, or citizenship for graduate students highlight the critical role of the educational environment and lived experiences in their departments in shaping students' academic and professional paths. White graduate men's and women's consistency in their commitment to their studies and reconsidering the same educational path, compared to their 2SLGBTQ+ or racialized counterparts indicates that the engineering environment in the researched university is not fully responsive to the needs and values of racialized and gender non-conforming students. This evolution suggests a need for a deeper exploration of the diverse experiences across racial lines to foster supportive and inclusive academic environments. Moreover, the interplay of race and gender is pivotal in influencing graduates' decisions, underscoring the complexity of identity factors in educational pathways. These findings underscore the need for responsive and inclusive experiences in engineering departments to foster graduate study ambitions and highlight the importance of addressing gender disparities and enhancing support structures within engineering faculties to retain and encourage diverse student participation in graduate studies.

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Appendix A: Cross-Tabulation Table (% of participants in each category and significance)

	Undergraduate Participants						Graduate Participants					
	Considering Eng. graduate degree			Not Considering Eng. graduate degree			Reconsidering Eng. Graduate studies			Not reconsidering Eng. graduate studies		
	Same university	Else-where	Total	Non-Eng Graduate	No Graduate	Total	Same university	Else-where	Total	non-Eng Graduate	No graduate	Total
All participants	43	32.7	75.7	8.5	35.1	43.6	44	8.9	52.8	9.3	9.3	18.5
Gender												
Women	41.4	31.7	73.2	8.5	39	47.6	46.1	10.4	56.5	7.8	7.0	14.8
Men	51.3	38.5	89.7	2.6	25.6	28.2	41.3	5	46.2	10	6.2	16.2
2SLGBTQ+	37.2	27.9	65.1	11.6	37.2	48.8	41.2	11.8	52.9	11.8	19.6	31.4
Citizenship (ug: 0.05, g: 0.97)												
Domestic	41.5	29.6	71.1	10.4	36.3	46.7	43.6	9.0	52.6	7.7	11.0	18.6
International	53.6	50.0	103.6	0.0	25.0	25.0	44.3	7.9	52.3	11.4	6.8	18.2
Race (ug: 0.4, g: 0.02)												
White	40	29.2	69.2	9.2	38.5	47.7	47.3	6.2	53.6	3.6	7.1	10.7
East-Asian	41.2	51.0	92.2	7.8	31.4	39.2	50.0	17.3	67.3	13.5	7.7	21.1
Other URM	44.4	19.0	63.5	6.3	41.3	47.6	38.5	6.2	44.8	13.5	12.5	26.0
Disability (ug: 0.1, g: 0.26)												
Yes	41.2	23.5	64.7	11.7	35.3	47.0	33.3	5.6	38.9	11.1	5.6	16.7
No	44.6	34.5	79.1	6.5	35.2	41.7	45.0	9.0	54.1	9.0	9.5	18.5
Level of Study (g: 0.007)												
MASc	N/A						46.7	9.3	56.0	9.3	9.3	18.7
Meng							47.1	8.0	55.2	7.0	12.6	19.5
PhD							40.7	9.9	50.6	12.3	6.2	18.5
Year of Study (ug: 0.03, g: 0.34)												
1	15.4	23.1	38.5	0	76.9	76.9	50.0	9.5	59.5	8.3	8.3	16.7
2	40.7	22.2	63.0	11.1	29.6	40.7	51.8	9.4	61.2	11.8	3.5	15.3
3	45.3	39.6	84.9	5.7	41.5	47.2	41.9	7.0	48.8	4.6	16.3	20.9
4	50.0	32.8	82.8	13.8	22.4	36.2	10.0	10.0	20.0	15.0	5.0	20.0
5+	35.7	35.7	71.4	0.0	35.7	35.7	18.7	6.2	25.0	6.2	31.2	37.5
Department (ug:0.31, g: 0.27)												
Industrial	16.7	50.0	66.7	16.7	50.0	66.7	29.2	4.2	33.3	4.2	12.5	16.7
Computer	30.0	20.0	50.0	10.0	40.0	50.0	61.1	5.6	66.7	22.2	5.6	27.8
Mechanical	23.1	23.1	46.2	23.1	38.5	61.5	50.0	10.0	60.0	10.0	10.0	20.0
Engineering Science	47.2	38.9	86.1	8.3	37.5	45.8	33.3	16.7	50.0	16.7	16.7	33.3
Chemical	35.3	41.2	76.5	5.9	23.5	29.4	56.2	6.2	62.5	14.6	4.2	18.7
Materials	50.0	18.7	68.7	6.2	37.5	43.7	21.7	13.0	34.8	4.3	13.0	17.4
Electrical	66.7	26.7	93.3	0.0	13.3	13.3	33.3	6.06	39.4	6.06	18.2	24.2
Biomedical	0.0	0.0	0.0	0.0	0.0	0.0	40.9	4.5	45.5	13.6	9.1	22.7
Civil	40.0	26.7	66.7	6.7	40.0	46.7	46.9	15.6	62.5	6.2	6.2	12.5
Aerospace	0.0	0.0	0.0	0.0	0.0	0.0	66.7	16.7	83.3	11.1	5.6	16.7
Bachelor origine (g: 0.63)												
Researched University	N/A						43.2	7.2	50.4	7.2	11.2	18.4
Other University							44.7	10.6	55.3	11.4	7.3	18.7
Family Education (ug: 0.25, g: 0.43)												
Engineer family member	47.6	36.9	84.5	5.8	32.0	37.9	42.4	6.3	48.7	8.9	10.1	19.0
No engineer family member	35.5	25.8	61.3	13.0	40.3	53.2	46.7	13.3	60.0	10.0	7.8	17.8

Gender & Citizenship (ug: 0.13, g: 0.11)												
Domestic Women	39.1	30.4	69.6	10.1	39.1	49.3	41.8	11.9	53.7	7.5	9.0	16.4
Domestic Men	45.1	38.7	83.9	3.2	29.0	32.3	49.1	3.6	52.7	5.4	7.3	12.7
Domestic 2SLGBTQ+	40.0	20.0	60.0	14.3	40.0	54.3	38.2	11.8	50.0	11.8	20.6	32.3
International Women	58.3	41.7	100.0	0.0	33.3	33.3	53.2	8.5	61.7	8.5	4.3	12.8
International Men	75.0	37.5	112.5	0.0	12.5	12.5	24.0	8.0	32.0	20.0	4.0	24.0
International 2SLGBTQ+	25.0	62.5	87.5	0.0	25.0	25.0	46.7	6.7	53.3	6.7	20.0	26.7
Gender & Race (ug: 0.009, g : 0.05)												
White Women	45.9	35.1	81.1	8.1	27.0	35.1	46.0	6.3	52.4	1.6	6.3	7.9
White Men	50.0	30.0	80.0	0.0	40.0	40.0	53.1	3.1	56.2	3.1	6.2	9.4
White 2SLGBTQ+	22.2	16.7	38.9	16.7	61.1	77.8	41.2	11.8	52.9	11.8	11.8	23.5
Racialized Women	37.0	28.3	65.2	8.7	50.0	58.7	49.1	14.0	63.2	15.8	7.0	22.8
Racialized Men	53.1	40.6	93.7	3.1	21.9	25.0	35.3	5.9	41.2	13.7	5.9	19.6
Racialized 2SLGBTQ+	41.9	29.0	71.0	6.4	32.3	38.7	41.7	11.1	52.8	11.1	22.2	33.3
Gender & Year of Study (ug: 0.05, g : 0.01)												
Y1-2, Women	29.2	25.0	54.2	12.5	50.0	62.5	48.7	10.2	10.2	11.5	5.1	16.6
Y1-2, Men	50.0	25.0	75.0	0.0	12.5	12.5	48.2	7.1	7.1	8.9	3.6	12.5
Y1-2, 2SLGBTQ+	33.3	11.1	44.4	0.0	55.5	55.5	57.6	12.1	12.1	9.1	12.1	21.2
Y3-4, Women	46.0	32.0	78.0	8.0	38	46.0	45.4	12.1	12.1	0.0	9.1	9.1
Y3-4, Men	55.2	41.4	96.5	3.4	27.6	31.0	29.4	0.0	0.0	17.6	5.9	23.5
Y3-4, 2SLGBTQ+	38.7	35.5	74.2	16.2	29.0	45.2	0.0	7.7	7.7	15.4	30.8	46.1
Y5+, Women	50.0	50.0	100.	0.0	12.5	12.5	0.0	0.0	0.0	0.0	25.0	25.0
Y5+, Men	0.0	50.0	50.0	0.0	50.0	50.0	14.3	0.0	0.0	0.0	28.6	28.6
Y5+, 2SLGBTQ+	33.3	0.0	33.3	0.0	66.7	66.7	40.0	20.0	20.0	20.0	40.0	60.0
Gender & Family Education (ug: 0.26, g : 0.18)												
Women & Eng. Family member	47.3	34.5	81.8	3.6	38.2	41.8	47.5	5.0	52.5	6.2	6.2	12.5
Men & Eng. Family member	59.1	50.0	109.1	0.0	13.6	13.6	38.3	6.4	44.7	10.6	6.4	17.0
2SLGBTQ+ & Eng. Family member	38.5	30.8	69.2	11.5	34.6	46.2	33.3	10.0	43.3	13.3	26.7	40.0
Women & Non-Eng. Family member	29.6	25.9	55.6	18.5	40.7	59.3	42.9	22.9	65.7	11.4	8.6	20.0
Men & Non-Eng. Family member	41.2	23.5	64.7	5.9	41.2	47.1	45.4	3.0	48.5	9.1	6.1	15.1
2SLGBTQ+ & Non-Eng. Family member	35.3	23.5	58.8	11.8	41.2	52.9	52.4	14.3	66.7	9.5	9.5	19.0