Gendered patterns in first-year engineering students' career aspirations and expectations

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Introduction

In the last decade the representation of women at the undergraduate engineering level has slowly but steadily increased, reaching 24% Canada-wide in 2020 [1]. At the institution providing the setting for the present study women now make up nearly 40% of the undergraduate cohort suggesting a promising trend toward gender equity. However, representation of women among licensed Professional Engineers (P.Eng.) has not kept pace, with women comprising only 20% of newly licensed Canadian P.Eng.'s each year and just 14% of Professional Engineers overall [2-3]. This representation gap in the profession is compounded with the low rates of licensure among engineering graduates in general [3], making the number of female P.Eng.'s in Canada exceedingly small. Underrepresentation of women in the engineering profession has been explored in the engineering education and organizational behaviour literature, with gaps variously attributed to a leaky pipeline through which women in STEM increasingly fall as they progress in their careers [4], a forceful stratification out of technical roles and into more stereotypically female roles [], a "chilly climate" of gender dynamics in school or work [6-7], and low identification with the profession [8-9]. Engineers Canada, through its "30-by-30" campaign, has set out a goal for women to make up 30% of newly licensed engineers by 2030, nearly equalizing the rates of licensure between men and women engineering graduates [2]. Although it is difficult to measure the eventual rate of licensure of each graduating class due to the requirement of accumulating at least 4 years of qualifying work experience, Engineers Canada has estimated that less than 40% of engineering graduates go on to receive a license. The other 60% are often viewed as having exited the profession, due to the strict legal definition of engineering in Canada (only licensed Professional Engineers may market themselves as "engineers"). Despite declining rates of professional licensure, regulation remains an underlying assumption of engineering education in Canada, where undergraduate curricula are aligned with the Canadian Engineering Accreditation Board's requirements to ensure graduates' academic eligibility for licensure.

This study explores first-year engineering students' goals and expectations around professional engineering in general and through a gender lens, through secondary use of a student survey. These first-year students are an interesting cohort to study because they have opted-in to a work-integrated learning program at the university. The program allows students to leave school for 12-16 months between their third and fourth years to work full time in an industry of interest, before returning to school to complete their final year of their engineering degree. This program is intended to provide students with hands on industrial experience and help them clarify their career interests. Work-integrated learning is widely accepted as an integral part of engineering education, as these experiences have been shown to improve students' vocational self-concept and work self-efficacy, as well as provide higher starting salaries post-graduation [10-11]. In the context of this study, enrolment in the program may signal students' intent to be part of the

engineering profession, or at least to obtain some professional experience in the field of their degree. However, given that the students are in their first year, we assume that they remain at an early stage of professional socialization. Therefore, their expectations for the profession and their own career trajectories may reflect their implicit assumptions about engineering and serve as a baseline for future study of the impacts of both the engineering curriculum and the work-integrated learning programming.

Using primarily quantitative survey data, we explore first-year engineering students' career aspirations and the paths they are on to get there. We will discuss the implications of students' diverging paths on the future of the profession, raise questions around the metrics we are using to measure women's participation in engineering, and present opportunities for engineering educators to support students in transforming the profession.

Methods

Data Source

This study involved secondary use of data from a survey administered by the engineering career centre at a public, urban university in Canada. The sample (N=1,275), representing the majority of the first-year class, comprised 38% women and 62% men. All members of the sample were enrolled at the time in the career centre's work-integrated learning program. At the university under study, the programming begins in students' first year with a series of preparatory modules covering career possibilities, job search strategies, personal branding, etc., culminating in the completion of the reflection survey. As previously mentioned, we are analyzing this data secondarily; the primary purpose of the survey from the career centre's perspective was to provide students with an opportunity to reflect on their career interests, skills, beliefs, etc., to ensure completion of the educational modules, and to collect program feedback. Thus, the survey questions were not necessarily designed for scholarly analysis and provide various levels of relevant insight into engineering students' career aspirations. Given our interest in the (variable) significance of professional licensure, we have chosen to explore students' expectations for their careers (their intention to become a Professional Engineer) and the diverging paths they are on (industries of interest, professional values, beliefs).

Analysis Methods

The survey questions included multiple choice, Likert scale, and open-ended text responses. In addition to descriptive statistics, chi-square tests of association were conducted to determine if there were relationships between demographics and variables of interest. Some questions were asked as multiple response questions where students could select 3 or more options. These types of questions present analytical challenges as they violate an assumption of the chi-square test, that each member of the sample only appears once in the responses. For these questions, the SPSS Column Proportions test was used at a 5% significance level. One open-ended follow-up question was explored using qualitative thematic analysis and constant comparison methods [12-13], with responses coded until saturation. These responses were first disaggregated by gender

and citizenship statuses (resulting in 6 demographic groups) and were then coded in batches to ensure representation of minority populations.

Results

Overall, we found that men and women students share some of the same professional goals but appear to be on different paths to try to achieve them in terms of their specific industries of interest as well as their professional values. The students are interested in a wide variety of engineering industries spanning from traditional to emerging, and they are seeking both to make an impact on the world around them and to feed their own intellectual curiosity. The following sections will explore the analysis of each selected survey question.

Intention to become Professional Engineers

Students were asked to rate their agreement with the statement "I intend to become a licensed Professional Engineer" on a 5-point Likert scale. The vast majority (77.7%) indicated that they agree, 19.5% were neutral, and only 2.8% indicated that they did not intend to seek licensure. A 2017 report by Engineer's Canada similarly found that 80% of graduates intended to become a P.Eng., although it is estimated that less than 40% of graduates actually receive licensure [14]. Interestingly, we found no significant association between gender and intention to pursue licensure, despite the underrepresentation of women in the profession. Although the students' expectations for licensure are not reflective of the reality of the engineering workforce today, it is noteworthy that both men's and women's expectations of being part of the profession are in alignment. This may suggest that what students are taught in first year (whether explicitly or implicitly) about the importance of licensure is being understood/accepted equally by men and women.

We did however find an association between intent to become a P.Eng. and engineering discipline of enrolment ($a<.001$, Figure 1), using the chi-squared test of association. The chi-squared test evaluates the null hypothesis by calculating theoretical proportions of group members selecting certain responses (in this case the proportion of students in each discipline who are intending to be licensed) assuming that all groups are equally likely to select each response (that all disciplines are equally likely to intend to be licensed.) If the observed proportions are significantly different from the theoretical proportions, then the null hypothesis is rejected and there is an association between the two variables. Due to the small number of people in most disciplines disagreeing or strongly disagreeing with the statement ($n<5$, impairing the validity of the chi-squared test), the 5-point Likert scale was condensed to a binary response: intending to obtain P.Eng. (Agree + Strongly Agree) or not necessarily intending to obtain P.Eng. (Neutral + Disagree + Strongly Disagree). After finding the significant association overall, we conducted a post-hoc test to identify which disciplines specifically had significant variance from the theoretical proportions (Table 1); students in Civil, Materials, and Mechanical Engineering were significantly more likely to intend to become licensed, while students in Engineering Science (an accelerated program) and Industrial Engineering were significantly less likely to intend to. Students in Electrical, Computer, Mineral, Track One (a non-specialized first

year engineering program), and Chemical Engineering were not significantly different from the theoretical proportion.

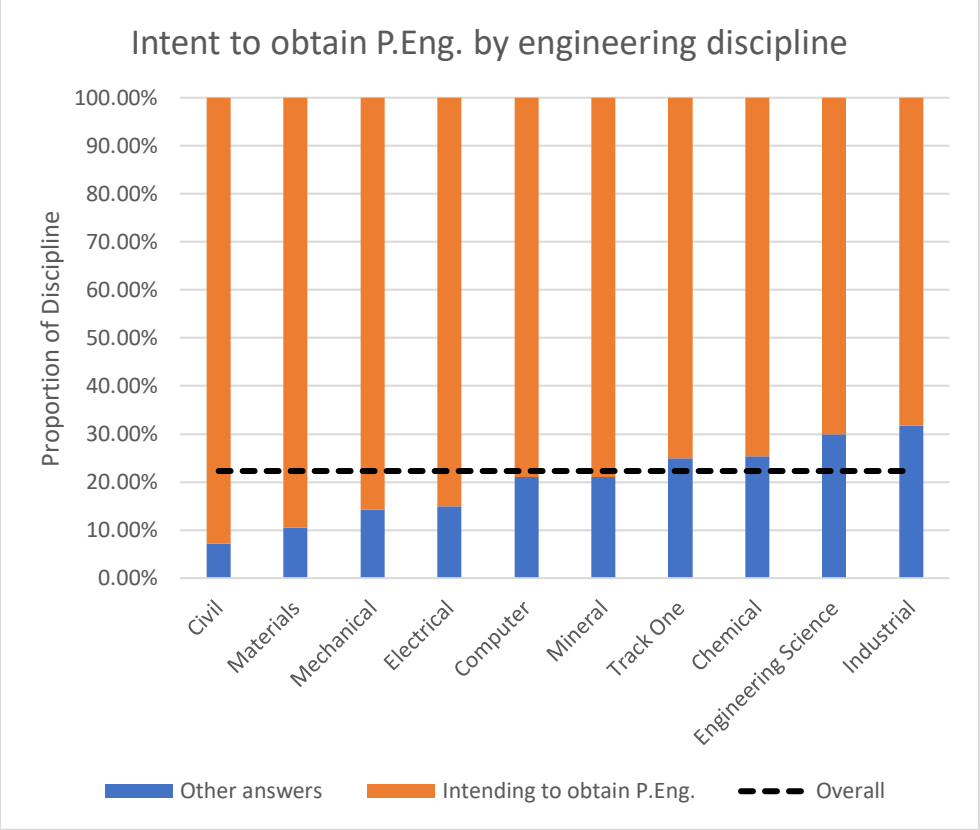

Figure 1. Intent to obtain licensure by undergraduate engineering discipline, with intent condensed from 5-point Likert scale to binary response. The proportion for the overall sample (77.7% intending to obtain P.Eng., 22.3% other answers) is shown for reference. There is a significant association between intent and discipline (a<.001).

Table 1. Intent to obtain licensure by engineering discipline, with disciplines ordered from most to least P.Eng. intent. Proportions are shown only for disciplines with significant association with intent (* signifies positive association, ** signifies negative association).

Discipline	*Other answers*	Intending to obtain P.Eng.
Civil	7.2%	*92.8%
Materials	10.5%	*89.5%
Mechanical	14.20%	*85.8%
Electrical	-	-
Computer	-	-
Mineral	-	-
Track One	-	-

Chemical	-	-
Engineering Science	29.9%	**70.1%
Industrial	31.8%	**68.2%
Overall	22.3%	77.7%

For the 5 disciplines with significant association with P.Eng. intent, we further disaggregated each discipline's responses by gender and still found no significant association between the students' intent to pursue P.Eng. and student gender. This suggests that women's and men's discipline-specific goals are in alignment.

Career Interests

Students were asked to choose their top three industries of interest from a list of industries who often hire work-integrated learning program students, according to the career centre. Overall, the top three industries were digital technology related: Computer Software; Electrical, Electronics, and Semiconductors; and IT, Security, and Services. These were followed by a strong interest in Banking, Finance, and Investing. The more traditional engineering industries of Automotive; Oil, Energy, and Utilities; and Civil Engineering, Construction, and Building Materials fell in the bottom half of the list. The response "Other" does not represent the researchers' combination of other low scoring industries, but rather was provided to the students as an option they could select if they were interested in an industry that was not on the list provided.

We were particularly interested in any gendered patterns in students' industry interests, as this might suggest that men and women students are on differing engineering career paths (for a variety of reasons), despite having the same goals to be part of the profession more broadly. We disaggregated responses by gender and created SPSS Multiple Response Tables with Column Proportions significance testing at a 0.05 significance level (the selection of multiple industries of interest meant that we could not perform a chi-squared test for association overall) (Table 2). Figure 2 below shows the proportion of women and men selecting each industry in their top three, as well as the corresponding proportion of the sample overall for comparison. We found that men were significantly more likely than women to select Computer Software; Electrical, Electronic and Semiconductor; and Automotive sectors, whereas women were significantly more likely to select IT, Security, and Services; and Banking, Finance, and Investing, as well as being twice as likely as men to select Government Administration. Women were also significantly more likely than men to choose "Other," suggesting that they are more likely to be exploring emerging industries not currently identified by the career centre as a top work-integrated learning employer. Biomedical engineering was frequently mentioned by students in their open-ended comments as an "Other" industry they were interested in pursuing. While this suggests that women students may have unique career interests that extend beyond the confines of traditional engineering internships, this may have negative practical implications for their ability to find work-integrated learning positions that meet their professional goals. Finding positions outside of the career centre's network of usual employers may require additional time and effort by

students. If this additional labour is largely being performed by the women students, there may be gendered impacts on students' time management and academic performance during the job application cycle.

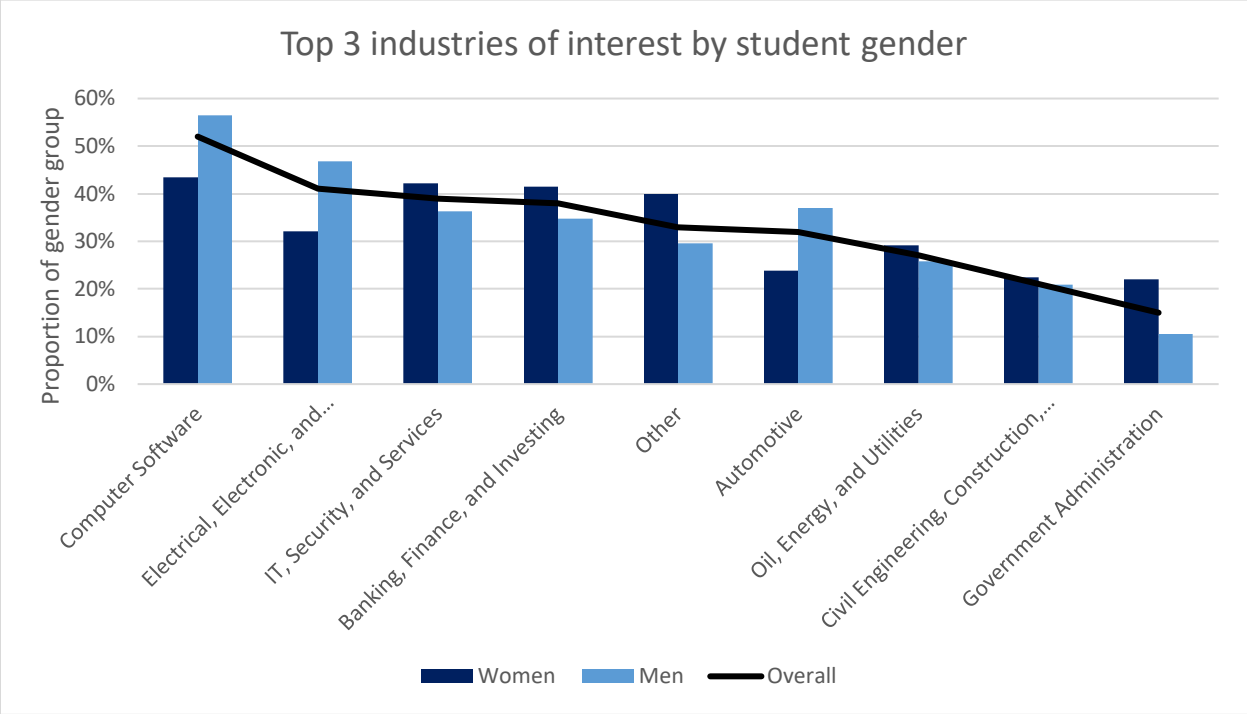

Figure 2. Proportion of students selecting each industry in their top 3, by gender. The proportion of the overall sample selecting each industry is overlaid for reference.

Table 2. Proportion of students of each gender selecting industries in their top 3. Industries with significantly different responses between women and men are marked with * in the gender column with the higher level of interest. Industries without significant differences are marked with a dash.

Industry	*Women*	*Men*
Computer Software	43%	*56%
Electrical, Electronic, and Semiconductor	32%	*47%
IT, Security, and Services	*42%	36%
Banking, Finance, and Investing	*41%	35%
Other	*40%	30%
Automotive	24%	*37%
Oil, Energy, and Utilities	-	-
Civil Engineering, Construction, and Building Materials	-	-
Government Administration	*22%	11%

Students expanded upon their industry interests in an open-ended text response question, "Tell us about one of the industries you are interested in, either from the list above or another industry that interests you more. What is one strategy you can use over the next year to learn more about the skills this industry requires and the future of this industry?" In our analysis we were not particularly interested in the students' strategies (they overwhelmingly consisted of speaking to upper year students, teaching assistants, and professors about industries), but rather the open-ended invitation to share more about their interests. Given the somewhat vague wording of the question, some students ignored this invitation to expand on their interests, but many took the opportunity to explain why they are interested in pursuing certain careers. From these responses, we identified five main themes. We found that students are interested in their chosen engineering industries because:

1. They want to do important work and make an impact on the world,
2. They think the industry will be intellectually fulfilling,
3. The industry offers them certain benefits,
4. They have positive prior experiences with field, and
5. N/A. Students are uncertain about interests.

Each theme describes several codes from the responses, summarized in the table below. The most common theme was wanting to make an impact. Many students were acutely aware of the climate crisis they are growing up in and want to use their engineering skills to further development of green energy and electric vehicles. Students interested in biomedical and pharmaceutical engineering particularly expressed a concern for human welfare and a desire to improve lives. In addition to these altruistic ways to impact the world, some students seemed more focused on doing something big or important, setting their sights on industries they view as highly influential in the functioning of modern society, such as software and finance. Many students indicated that some aspect of engineering has "always fascinated" them and they want to apply innovative technology to the real world. Others were more pragmatic in their interests, commenting on the potential for job growth and financial stability in the field. Lastly, on two opposite sides of the spectrum, some students cited prior exposure to an industry through extracurricular work and family as reason for their interests; others rebuffed the question, saying they did not have enough exposure to engineering practice to be sure of their interests.

Table 3. Themes and codes identified from students' elaboration on the reasons for their industry interests.

Theme	**Codes**
Want to do important work, make an impact on the world	• Environmental protection and sustainability • Improve lives, concern for others' welfare • Importance of the industry as it relates to societal function and other industries
Industry is intellectually fulfilling	• Curiosity, fascination, long term personal interests • Innovation, problem solving, applying tech to the real world • Field utilizes their personal strengths

	• Field is interdisciplinary or has strong interpersonal elements
Industry offers them certain benefits	• Job growth, field has "potential" • Wide variety of opportunities in field • Financial stability and/or gain • Path to future goals (e.g., graduate studies)
Prior experience with industry	• Field is related to their extracurriculars or hobbies • Field is related to their previous work/internships • Influence from parents and other family • Influence from broader environment (e.g., industry is popular in their home province)
Uncertainty	• Interested in many different fields, keeping an open mind • They haven't had courses about their industry of interest yet • They have had related courses, but are not sure of what practicing engineers actually do • They don't think school teaches them about the real working world

Professional Values

Students were asked to choose their top 3 professional values from a list (Figure 3). Overall, the top 3 values chosen by the students were Achievement, Financial Prosperity, and Creativity. When disaggregating responses by gender, the top 3 values chosen by men were the same as the overall group. However, the top 3 values chosen by women differed in the choice of Responsibility instead of Financial Prosperity. For 6 of the professional values, there were statistically significant differences in the rate of choice by women and men (SPSS Column Proportions test at a 0.05 significance level) (Table 4). Women were significantly more likely to choose Responsibility, Care for Others, and Care for the Environment, suggesting a value set that leans toward a collectivist mindset and the ethic of care. Men on the other hand were significantly more likely to choose Financial Prosperity, Scientific Understanding, and Health and Activity, suggesting the valuing of individual development and personal wellness.

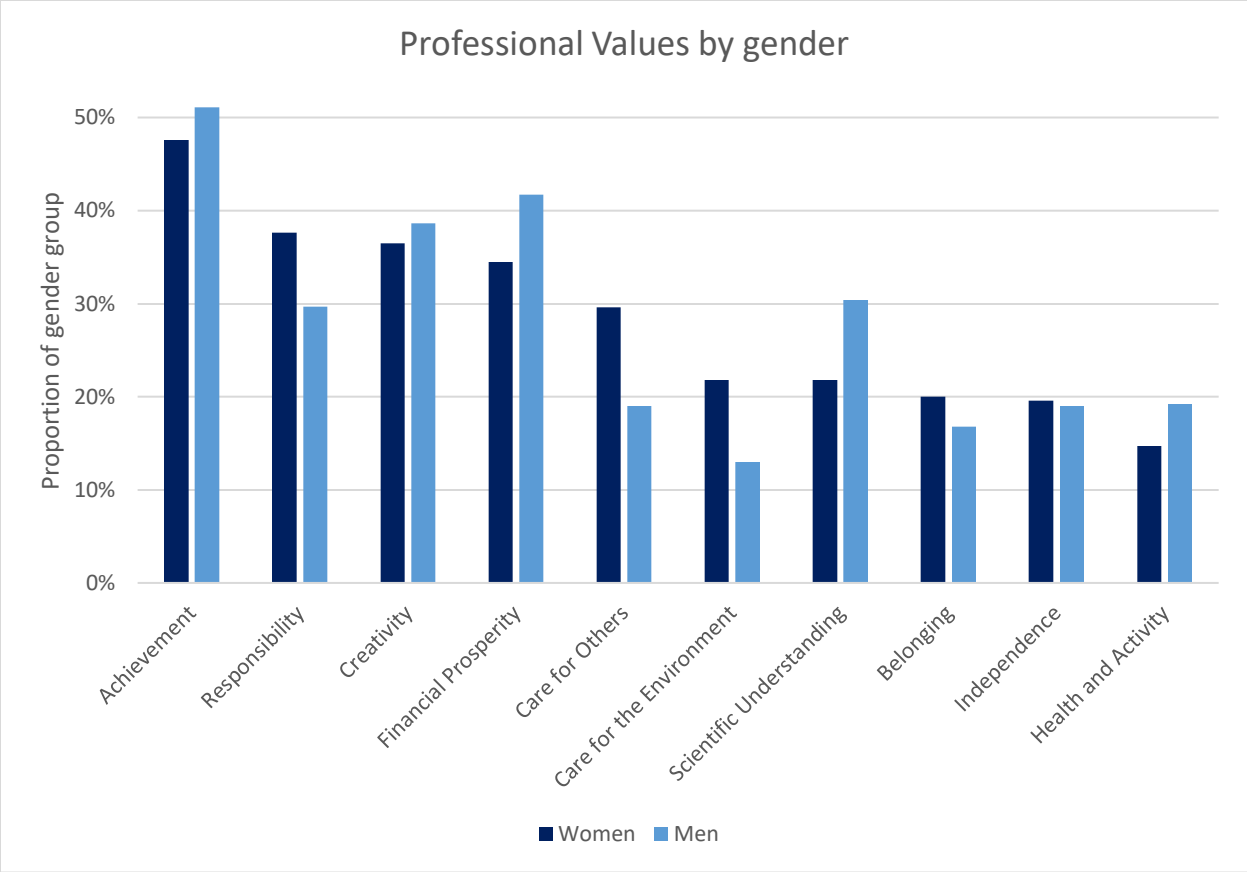

Figure 3. Top 3 professional values by gender, ordered by proportion of women selecting each value. The lowest 4 values for both men and women were humility, loyalty, spirituality, and privacy (not shown). These were under 10% for both men and women and none were statistically significant.

Table 4. Men's and women's top 3 professional values, with statistically significant differences between genders marked by * in the column with the higher level of value selection. Values without statistically significant differences are marked by a dash. Again, the lowest 4 values for both men and women are not shown.

Values	*Women*	*Men*
Achievement	-	-
Responsibility	*37.6%	29.7%
Creativity	-	-
Financial Prosperity	34.5%	*41.7%
Care for Others	*29.6%	19.0%
Care for the Environment	*21.8%	13.0%
Scientific Understanding	21.8%	*30.4%
Belonging	-	-

Independence	-	-
Health and Activity	14.7%	*19.2%

Career Beliefs

Finally, students were asked to rate their degree of agreement with two beliefs about the clarity of their academic plans and the flexibility of their professional plans, both of which had significant association with gender (a<.001 and a<.022 respectively). In response to the statement "I have a clear idea of the topics and courses I want to study during my degree," women were significantly more likely than men to disagree or be neutral, and they were significantly less likely to strongly agree.

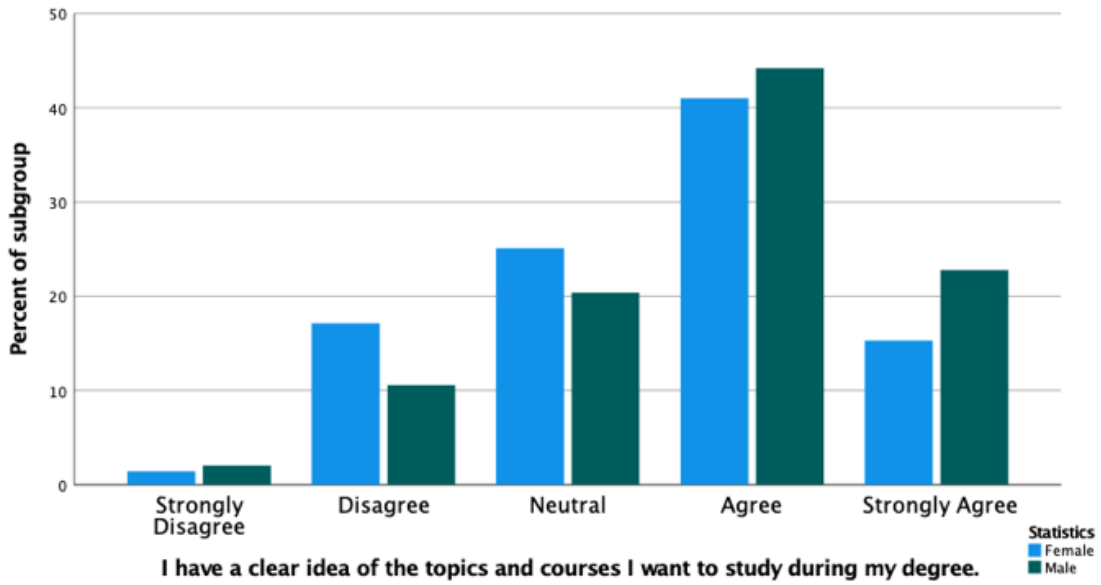

Figure 4. Clarity of vision for academic future, by gender.

In response to the statement "I can explore diverse career possibilities instead of focusing on just one job or possibility," men were significantly more likely than women to be neutral. However, so few students disagreed with this statement that the sentiment overall is clearly positive for both men and women.

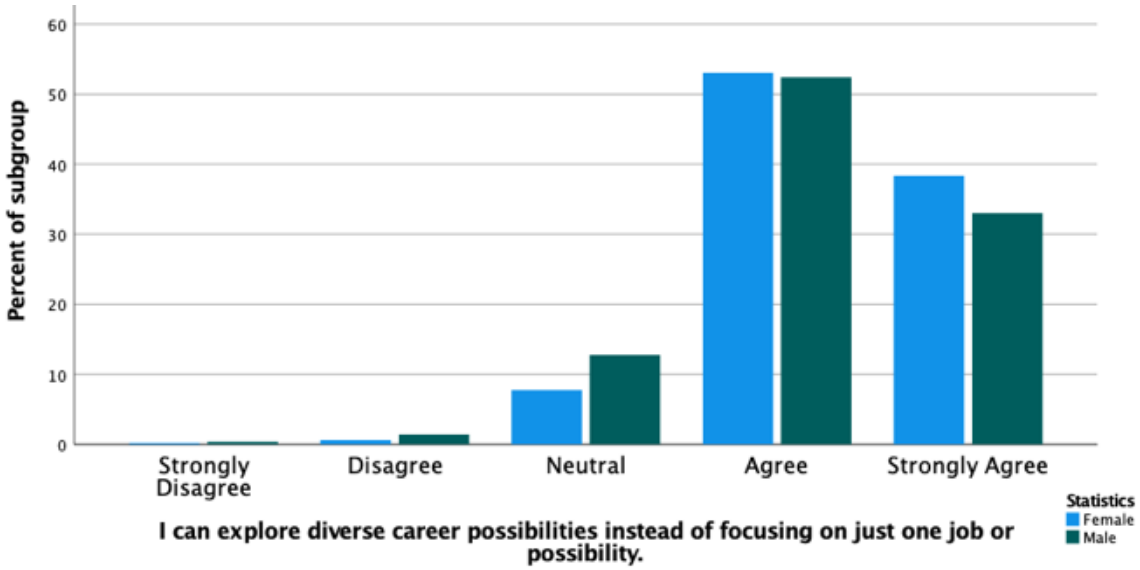

Figure 5. Openness to diverse career possibilities, by gender.

Taken together, these findings suggest that while both male and female engineering students are largely open to diverse career possibilities, women express much less certainty about what they want to do academically. This openness may make short term decisions like planning their engineering course load more difficult.

Discussion

Our findings paint a picture of a highly motivated first year class looking to make their mark on the world through design, while indulging their own intellectual curiosity. They view engineering as a stable and lucrative career as well as a place to innovate and be creative. In some cases, the students' understanding of engineering seems to transcend narrow professional boundaries and may reflect what historian Rosalind Williams calls the "expansive disintegration" of engineering [15-16]. Stevens et al. explore our changing professional landscape in the *Cambridge Handbook of Engineering Education Research*, explaining this expansive disintegration as a realization that if "nearly everything involves engineering, then nothing is distinctly engineering" [16]. For example, students in our sample who said they plan to work in finance because they view it as a critical facilitator of other industries may see themselves performing "engineering-like activities" [16]. The sample's general preference for software, electronics, IT, and banking over automotive, utilities, and construction reifies this ongoing shift in the engineering profession from something distinctly defined to something "heterogeneous" [16]. The allure of high-paying, fast-paced tech jobs and the growing demand for engineering skillsets in other sectors appear to be drawing students into engineering undergraduate programs, but then out of the profession as it is currently bounded. Interestingly, these same students are fully intending and expecting to be part of the profession via licensure, even if they are not interested in traditional engineering industries. We were not able to explore in this study *why* these students intend to be licensed (a limitation of our use of secondary data), but anecdotally,

reasons range from fulfilling a legal requirement to seeking a resume booster to achieving a sentimental life milestone - or perhaps at their early stage of professional awareness, the students simply believe it's what every engineer does. Regardless, obtaining a P.Eng. is a goal shared among men and women in equal measure. Within our current system of professionalization, many of these students will not need (and/or be eligible for) licensure to work in their area of interest, creating a mismatch between their goals and the paths they are on.

This mismatch seems to be gendered, as women were more likely to indicate interest in career paths less often recognized as engineering-intensive (IT, banking, government administration) and to report values that align with sociotechnical work and the ethic of care (Responsibility, Care for Others, Care for Environment) [17]. While we (the authors, the readers) may accept a heterogenous and inclusive definition of engineering, it is important to recognize that this is not necessarily the norm and that the broader cultural understanding of engineering may shape our students' identification with and experience of the profession. Per Stevens [16], "there is a tendency among engineers to define "real" engineering in terms of the technical, "nuts and bolts," scientific and mathematical labor, and to locate the social aspects of heterogeneous engineering outside of "real" engineering." We see these gender dynamics at play in our results, with men more likely to be interested in the "nuts and bolts" engineering paths of electrical and automotive (as well as software engineering) and to report values related to self-interest and scientific rigour. Sociotechnical work requiring "soft skills" has long been regarded as feminine and low status, and purely technical work requiring "hard skills" regarded as masculine and high status [18-19]. Our findings of early gender-based career path streaming are consistent with the literature that shows stratification of women into certain managerial or people-focused roles and men into technical roles where they are more likely to identify and be identified as engineers [20-21]. Thus, the exclusivity and male domination of professional engineering can be considered both a cause and a symptom of ongoing gender discrimination and deeply rooted gender expectations in the profession.

To achieve their goal of becoming Professional Engineers, students will have to fulfill an engineering work experience requirement which involves working under the supervision of a P.Eng. and performing certain tasks considered to be engineering (determined at the discretion of the regulator) [22]. This type of work experience is more readily available in the traditional paths chosen by the men students than the women, creating a structural barrier to applying for licensure. Given the need to be supervised by a P.Eng., it is difficult to become licensed in an emerging industry that does not already have an abundance of practicing Professional Engineers. We also note that the Engineer-in-Training program, designed to assist engineering graduates in navigating these regulations and meeting the requirements for licensure, is being scrapped in the summer of 2023, leaving students to interpret their experience on their own [23].

Our focus on P.Eng. interest should not be interpreted as a judgement that professional engineering is the only way for engineering graduates to have a fulfilling and successful career. On the contrary, we recognize that engineering graduates pursue and excel in an ever-widening range of careers as engineering skills/thinking are highly sought after in many other sectors. However, even in the current professional engineering climate (with long declining rates of licensure among engineering graduates), the licensure metric remains relevant as a proxy for other signals: who is streaming into which engineering fields and roles, who holds legal and

social power within engineering organizations, where we should look for evidence of systemic barriers, etc. In Canada even the use of the word "engineer" to refer to one's occupation is regulated, reserved for licensed P.Eng.'s only [24]. (Similar attempts at regulation have been made in the US but have been met with First Amendment related push-back [25].) It is no surprise then that research has linked undergraduate students' lack of engineering identity to not yet being licensed [26-28]. Even as engineering educators are working to expand our understanding of engineering identity to reflect more diverse experiences and include the practice of sociotechnical work, the exclusivity of licensure may be standing in the way.

Implications

As engineering educators, we should continue to engage in conversation around what successful engineering careers can look like. The engineering profession is at a cross-roads - how can we balance preparing our students for more traditional engineering roles and for emerging ones? Should we guide students towards or away from professionalization? How can we support students in developing an engineering identity when it is *illegal* for them to say, "I am an engineer?"

While this study seems to have raised more questions than answers, our findings did suggest a few more concrete areas for improvement. We identified a need for better academic advising for women students to aid in degree exploration and planning. Additionally, although the vast majority of students agreed that they can explore diverse career possibilities, male students may benefit from learning more about diverse or non-linear engineering career paths.

Of course, more needs to be done to reduce the exclusion of women from male-dominated career paths. However, we want to be careful not to apply a deficit lens to the values, skills, and interests more likely to be expressed by women. On the contrary, certainly the world would be a better place if men were equally as likely as women to value Responsibility, Care for Others, and Care for the Environment, and to employ those values in their careers. Patriarchal systems of streaming and stratification limit everyone in our collective goals to engineer a better world. Engineering educators should stress the importance and relevance of these values in every-day engineering practice, not just in accreditation-mandated ethics courses.

Future Directions

Future work should explore the reasons students want to become Professional Engineers and perhaps track their interest longitudinally throughout their degrees and early careers. Of particular interest in Canada may be the impact of professional regulation on students' self-perception as engineers.

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