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Women Engineering Graduate Students Changing Professional Interests in Academia*

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The disproportionately low number of women in engineering faculty roles is concerning to academic administrators, faculty, and students. Prior studies have focused on engineering identity but not on how the interests of women engineering graduate students may change throughout their program progression. The research reported here focuses on the differences in the professional plans of women engineering graduate students early in their Ph.D. programs as compared to those near completion of their graduate studies. A mixed method study was conducted using survey and focus groups at a medium-sized, Midwestern, private institution during the summer 2021. A survey was sent to about 600 engineering PhD students (both male and female) with analysis primarily utilizing Kruskal-Wallis H tests. Additionally, focus groups of four to six students were conducted based on program progression and gender to better understand the quantitative findings. Survey responses were analyzed by program progression, gender, and international status. Results show that women engineering Ph.D. students' interest in an academic career decreases as they progress through their graduate studies. There are also differences between domestic and international Ph.D. students in terms of their professional interests which is entangled with their legal and immigration status. It is recommended that engineering graduate programs offer formal professional discernment opportunities for 2nd year Ph.D. students, both male and female, to help them to recognize the opportunities available to them upon program completion. And additionally, for Diversity, Equity and Inclusion efforts be expanded to consider the needs of graduate students in retention.

Keywords: Women; Graduate Student; Career Pathway; Professional Discernment

1. Literature Review

Prior studies have considered motivations as to why students pursue graduate studies, for example a study by Gueiren, Jayatilaka, and Ranasing [1], reported five factors: family/friends, intrinsic motivation, professor encouragement, having a research experience, and career progression. Jiang and Loui [2] corroborated the influence of family/friends as well as research experience on the decision to pursue graduate studies. A study by Ro, Lattuca, and Alcott [3] indicated that for engineering graduate studies, math preparation level and having co-curricular experiences were significant factors. More recently, it has been recognized that self-efficacy is a critical factor influencing a student's intention to pursue graduate studies; a one unit increase in self-efficacy resulted in an engineering student being 13x more likely to enroll in a Ph.D. program [4].

Persistence and retention among underrepresented engineering students has been an ongoing concern in engineering education [5, 6]. Literature has examined reasons for graduate students' departure from doctoral studies as well as academia as a whole [7–12]. Pressures and expectations of roles in academia, chilly climates, isolation, and other aspects of the environment pushed female graduates and academics to leave [13, 14]. There is concern that the reported attrition rates of graduate students do not account for how widespread the notion of discontinuance of a graduate program in engineering is; meaning that many engineering Ph.D. students (both male and female) may seriously consider discontinuance. If many engineering graduate students consider leaving their program prior to completion, it calls to question how those doubts translate to changes in professional plans upon degree completion. Both men and women reported considering leaving their program, but women were more likely to actually discontinue their studies [13].

One way in which persistence has been studied is through the exploration of career interest [16, 17]. In the context of undergraduates, social cognitive career theory has been utilized to understand different components of career interest such as life satisfaction and other elements of well-being [17, 19]. Additionally, components of identity, either originating from Gee's multiple identities theory or the disaggregation of engineering identity to specific components have been used to investigate how identity formation contributes to career goals [16]. Identity as it relates to graduate students' career interests has examined research and disciplinary (engineering) identity, attempting to

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explain how recognition, knowledge, and interests relate to intentions to pursue careers in fields such as academia, government, and industry. Choe and Borrego's [16] study demonstrated that engineering disciplinary identity has a negative correlation with academic career interest, as did length of time in a graduate program. A positive indicator of academic career interest was research identity. Graduate students' life experiences, including education and work impacted how they perceived the profession of engineering and therefore with their identification with the discipline [16].

McAlister and associates [20] reported that role identities of engineering, researcher, student, and educator were part of graduate studies but that the researcher role was critical for successful completion of graduate studies. The gap between women's presence in graduate engineering programs, and their underrepresentation in academic positions suggests issues exist preventing them from completing their programs and transiting into academic positions in engineering. On a national level, 23.9% of Engineering Ph.D.'s degrees are awarded to women, yet only 18.5% of Engineering Tenured / Tenure Track faculty members are women [21]. Once a student is enrolled in an engineering Ph.D. program, students have a chance to "see behind the curtain" and understand the pressures and expectations for research and publications [22]. During this formative time, graduate students are assessing themselves as compared to their peers and faculty advisors and in particular recognizing conflicts between their personal values and capabilities for being successful in a faculty role [23]. Faculty mentors are often excellent at providing guidance on preparation for a career in academia; but for the majority of graduate students that don't pursue the academy, they must seek other resources and mentorship for professional discernment [16].

These existing studies suggest that a change in interests or goals may occur during engineering graduate studies that results in engineering Ph.D. graduates pursuing a different professional pathway than that which originally motivated them to begin their studies. The authors in the current study sought to further expand upon the work done around engineering graduate students' career interests by focusing on the following research question:

How do graduate engineering students' career interests vary by sex, internationality, and academic level?

2. Background

This study was conducted in the College of Engineering at a medium sized, Midwestern, private institution. The Ph.D. students come from 5 degree granting departments: Aerospace and Mechanical Engineering, Civil and Environmental Engineering, Chemical and Biomolecular Engineering, Computer Science and Engineering, and Electrical Engineering. The sex distribution of graduate students invited to participate in this study was about 27% female/73% male. Across all of the engineering graduate programs there are around 600 Ph.D. students, the average time for program completion is 5.25 to 5.5 years.

3. Methods

This mixed method study is guided by the principles of a descriptive quantitative research methodology with follow-up focus group qualitative inquiry. In seeking to understand the career interests of graduate engineering students and how they change over the course of their time in their programs, there is not an effort here to prove a causal relationship, but to compare cross-sectional data across various students' years in their graduate programs. This study aims to examine what the career interests of graduate students are, how they change, and to what extent. As the descriptive analysis could be used to evaluate a phenomenon to answer questions relating to who and to what extent [24], descriptive quantitative methods were used to examine survey data to identify patterns about graduate students' career interests.

In the first stage, a survey was distributed pertaining to career interest, research identity, life satisfaction, support systems, and intention to complete their degree and persist into an engineering career. To further answer the research question, the second stage focus groups were conducted to elucidate factors that possibly contributed to female participants' interests in various engineering career sectors, such as academia, industry, and government. Finally, aggregated institutional career placement for engineering graduate students from 2011–2021 was used for comparison.

3.1 Survey

A Qualtrics survey comprising 20 questions was distributed to all graduate engineering students, both male and female. The survey was confidential but not anonymous. The survey was sent to 614 current graduate engineering students (Ph.D. students only), with 221 surveys being completed, a 36% response rate. Questions were adapted and inspired by Choe and Borrego's [16] instrument, in addition to aspects of Lent and Brown's Model of Career Self-Management [18]. Table 1 is a list of the survey questions administered. By collecting data from graduate students across years and demo-

Table 1. Summary of Survey Questions

Question	
Background	Was your previous degree in engineering? If yes, what discipline most closely describes your bachelor's degree. What year did you start the program?
Career Interest	How likely are you to pursue a career as a College professor/instructor/researcher after graduation? Describe why or why not a career as a College professor/instructor/researcher interests you. How likely are you to pursue a career in Industry after graduation? Describe why or why not a career in Industry interests you. How likely are you to pursue a career in Government after graduation? Describe why or why not a career in Government interests you. Describe why or why not a career in any other field interests you. My interest in an academic career has... since deciding on my graduate degree program. My interest in an industry career has... since deciding on graduate degree program. My interest in a government career has... since deciding on my graduate degree program.
Life Satisfaction: I am generally satisfied with. . .	My academic progress. My financial support. My research. The progress I am making on my goals. My choice in discipline. Academic career skills/identity. I am interested in my research topic. My current research topic aligns with my interests. I enjoy conducting my current research.
Relationships/Peer support	I have a peer group of graduate students that have similarly focused goals. I feel supported by my advisor.
Retention	I plan to complete my graduate degree program.
Persistence	After completing my graduate studies, I plan to work in a field related to the degree I am pursuing.

graphics, the results help to examine how different cohorts view career choices and how they change over the time spent in their program.

3.1.1 Participants

There were a total of 219 responses collected including both male and female engineering graduate students at the studied institution. The demographic information is summarized in Table 2. Women consist of 33.3% of participants, slightly more than the percentage of women present in graduate engineering programs as a whole (27%). International students, referred to as Non-Resident Aliens within the survey, comprised 49.8% of the sample whereas they represent 56% of engineering students.

3.1.2 Missing Data

After processing the raw data, the researchers first examined the missingness pattern of the 219 responded samples of survey results, using the ''MissMech'' R package in R 4.0.2 [25, 26]. The assumption of homoscedasticity was tested and the result indicated that the assumption was not violated at the 0.05 level of significance. Furthermore, the result of the test of missing completely at random (MCAR) of the sample rejected this assumption at the 95% significance level. Thus, any sample missing more than three-item responses were deleted for the concern of data quality and usability, which resulted in removing 11 samples of data. For the rest of the 208 responses, multiple imputation via ''Mice'' R package with predictive mean matching method was used to recover the partial complete data with five rounds of multiple imputations [26, 27].

3.1.3 Analysis

The purpose of the survey was to reveal information to guide the development of the questions and key areas in focus group interviews. First, the Spear-

Table 2. Participation Sample Demographics

	n	%
Sex	219	
Male	146	66.7
Female	73	33.3
Race		
White	76	34.7
Asian	11	5
Hispanic	15	6.8
African American	3	1.4
Two or more	5	2.3
Non-Resident Alien	109	49.8
Department		
Aerospace and Mechanical	58	26.5
Chemical and Biomolecular	50	22.8
Civil and Environmental	36	16.4
Computer Science	44	20.1
Electrical	31	14.2
Academic Level		
Early Years (in Year 1–2)	106	48.4
Middle Years (in Year 3-4)	59	27
Senior Years (in Year 5–7)	54	24.6

man's rank correlation test was computed first for all survey questions because all survey questions are constructed as Likert scale or yes/no responses. Spearman's rank correlation is a non-parametric statistical test suitable to measure the strength and direction of association between ordinal variables [28]. Similarly, the Kruskal-Wallis H test was adapted to compare the survey items across participants' sex, internationality, engineering departments, academic level, and their intersection. The skewness of all included variables ranged from -3.77 to 0.66 (9 out of 19 variables were highly skewed with the absolute values greater than 1), and the kurtosis of them ranged from –1.57 to 16.68 (3 out of 19 variables had excess kurtosis with absolute values greater than 3). Also considering the variables were ordinal, we chose to use Kruskal-Wallis H test as the non-parametric test alternative to ANOVA [29]. Though some items shared the same theme, no attempt was made to analyze the aggregated data since each question covered a unique aspect of the shared theme. Selected results were reported in the following section.

Open ended free response questions were analyzed to provide context to female participants' answers regarding their various career interests. Thematic analysis was conducted to elucidate both positive and negative perspectives of each career choice, with emphasis on the reasoning for interest or the lack thereof in an academic career. Quotes from participants' responses were chosen to reflect the themes presented. Themes gathered from qualitative analysis were used to inform the focus group discussion complementary to the results of found themes from the free response questions.

3.2 Focus Groups

Two focus groups were conducted to better understand the survey results. One group was comprised of women that were close to completing their Ph.D.'s (4 or more years into their program). The other group was women that were in the early stages of their Ph.D. programs (having started their program within the past 1 year). The discussion was semi-structured with the focus on career interests and goals, and specifically what progress they have made towards those goals, have the goals changed, and what barriers do they see for achieving their goals. Two of the researchers led the focus groups and met immediately after. Table 3 outlines the focus group guided questions.

4. Results/Discussions

This section presents the aggregated results of both the survey administration and the focus group discussions.

4.1 Survey Results

4.1.1 Correlation of Survey Items

Table 4 shows the mean, standard deviation, and Cronbach's alpha reliability (the diagonal of the matrix) for each survey question as well as the correlation between each item. The questions related to life satisfaction, relationships, career interests, retention and persistence were all on five-point Likert scale with a lower number corresponding to a more negative response and higher number corresponding to a more positive response. The statistically significant differences are denoted by asterisks as demonstrated in the note under Table 4.

Cronbach's alpha value for all survey results achieved at least 0.8, indicating that all items show a high level of internal consistency and are considered reliable [30]. Most items are correlated with each other. However, several items stand out, which were explored through the qualitative

Table 3. Focus Group Interview Questions

Topic	Question
Background	Why did you decide to pursue a graduate degree?
Career	What are your career goals? How have these changed during grad school? What skills do you consider necessary for this career? What barriers exist to achieving your career goals? Can you picture yourself in the role that your advisor has? Which people in your life have impacted your career goals? how? Why have your goals changed?
Program	How has your program prepared you for your desired career? What support do they provide? How does your advisor support you? How do your peers support you?
Other	How comfortable are you teaching engineering? Have you mentored students? How confident are you in conducting research and communicating your findings?

Table 4. Correlations between Survey Item

	Avg	SD	Life Satisfaction								Relationships		Career interests				Interest change			Retention Persistence	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Life Satisfaction																					
1. Research interest	4.34	0.94	*0.80*																		
2. Professional goals	4.11	1.00	0.7***	*0.81*																	
3. Research enjoyment	4.15	1.01	0.71***	0.58 ***	*0.80*																
4. Academic progress	3.88	1.05	0.47***	0.42 ***	0.54***	*0.81*															
5. Financial support	4.14	1.04	0.15	0.17	0.13	0.24	*0.82*														
6. Research	4.04	1.04	0.63***	0.56 ***	0.75***	0.66***	0.20	*0.80*													
7. Goal progress	3.73	1.07	0.43***	0.44 ***	0.56***	0.71***	0.25*	0.69***	*0.80*												
8. Discipline	4.19	0.91	0.61***	0.50 ***	0.53***	0.53***	0.26*	0.64***	0.49***	*0.80*											
Relationships																					
9. Peer group	3.66	1.15	0.36***	0.31 ***	0.42***	0.34***	0.26*	0.36***	0.33***	0.25*	*0.81*										
10. Advisor	4.23	1.05	0.42***	0.29 **	0.50***	0.50***	0.25	0.58***	0.52***	0.40 ***	0.31 ***	*0.81*									
Career Interests																					
11. Academia	3.06	1.20	0.16	0.25	0.15	0.17	0.34***	0.20	0.19	0.26*	0.04	0.13	*0.83*								
12. Industry	3.58	1.01	0.09	<0.01	0.06	0.04	0.10	0.03	0.05	–0.09	0.09	0.08	–0.51***	*0.84*							
13. Government	2.80	1.12	0.09	0.09	0.10	–0.03	–0.05	0.03	0.09	0.05	0.14	–0.04	0.02	–0.06	*0.83*						
14. Other	0.34	0.48	0.04	–0.04	0.05	0.02	0.03	–0.03	<0.01	–0.14	0.04	0.11	<0.01	<0.01	0.10	*0.84*					
Interest Change																					
15. Academia	2.98	1.21	0.19	0.33 ***	0.25*	0.27*	–0.02	0.24	0.30**	0.20	0.09	0.16	0.59***	–0.25*	0.01	–0.02	*0.82*				
16. Industry	3.46	0.96	0.13	<0.01	0.04	<0.01	0.13	0.08	0.02	–0.09	0.01	0.08	–0.25	0.59***	–0.11	0.10	–0.22	*0.84*			
17. Government	3.12	0.85	0.06	0.08	0.03	0.02	–0.04	0.07	0.11	0.12	0.07	0.07	<0.01	–0.08	0.54***	0.02	<0.01	–0.11	*0.83*		
Retention and Persistence																					
18. Retention	4.78	0.61	0.26*	0.21	0.30**	0.26*	0.07	0.28**	0.21	0.39 ***	0.20	0.17	0.16	–0.07	–0.05	–0.14	0.10	–0.07	–0.05	*0.82*	
19. Persistence	4.50	0.83	0.34***	0.35 ***	0.39***	0.25*	0.14	0.38***	0.27*	0.39 ***	0.27*	0.16	0.21	0.01	<0.01	–0.21	0.18	–0.04	–0.06	0.47***	*0.82*

Note. * $p < 0.05$, two-tailed; ** $p < 0.01$,*** $p < 0.001$, two-tailed; bold and italicized numbers represent attributes' Cronbach's alpha reliability.

responses and focus groups. The set of questions related to career interests and change of career interests seems to be independent with the majority of the survey items. Students' career interest in the type of job appears to be relatively stable as their interest in the type of job correlates to each the interest change in the corresponding type but not for other job types. Combining this with the mean scores for career change related questions to be around 3 (neither increase nor decrease), it might imply that most graduate students' academic experiences do not impactfully influence how they perceive their ideal careers.

4.1.2 Selected Descriptive Statistics Analysis Results

4.1.2.1 Differences in Financial Perspectives

Two interesting findings relate to pay. Male and female graduate students in this study earn similar amounts. However, women expressed a higher satisfaction with their financial support than their male counterparts. Also, men expressed a higher level of interest in a professional pathway in industry. Looking at the median salary of early career doctorates, by doctoral degree characteristics and position type shows that for engineering Ph.D.'s faculty positions make $90,000/year on average as compared to $110,000/per year for non-faculty positions [31]. There have been many economic studies of gender pay gap, which includes lower expectations of earning potential overall for women as compared to their peers in the same STEM field [32, 33]. And women in math and computer science are much more likely to underestimate the average salary by more than 10% as compared to their male counterparts [33]. Therefore, satisfaction with the expected salary for various career types may be a differentiating factor in male and female career placement. Fig. 1 shows the career placement data for male and female students at the institution studied over the past 10 years. Women are more likely to take on lower paying academic positions (non-TTT, adjunct, or postdoc) as opposed to their male counterparts. Women engineering Ph.D. are also more likely to take professional roles in government and less likely to take roles in industry compared to similarly trained men. This follows a national trend, NSF reports that 39% of women engineering Ph.D.'s take industry roles versus 45% of male engineering Ph.D.'s [34].

From the free-response survey items it was clear that formative positive experiences in industry or academia are important in student decision making, and further students that are driven by autonomy place a different priority on pay.

> "As I am near completion, I applied for both academic (postdoctoral fellowships) and industry jobs. My experience with academia has been good in comparison to industry. While the pay is a lot higher, the freedom to choose your projects is very limited. If I ever take up an industry job, it's definitely going to be for financial reasons." (Computer Science, Late level student)

4.1.2.2 Changes in Professional Interests

Fig. 2 shows the degree of professional interest of female, domestic graduate students and how their interest changes as they progress through their studies. For academic pathways, there is a clear drop off in interest at the mid-point of their studies, potentially related to qualifying exams or simply as the life and rigors of academic pathways are demystified. Interest in industry careers increases slightly over degree progression, while interest in govern-

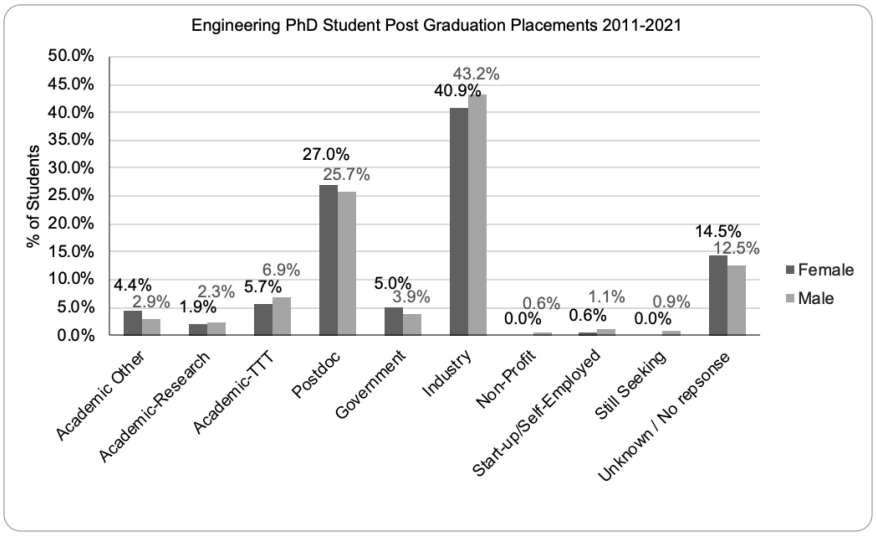

Fig. 1. Career Placements for Male and Female Ph.D. Students from 2011–2021

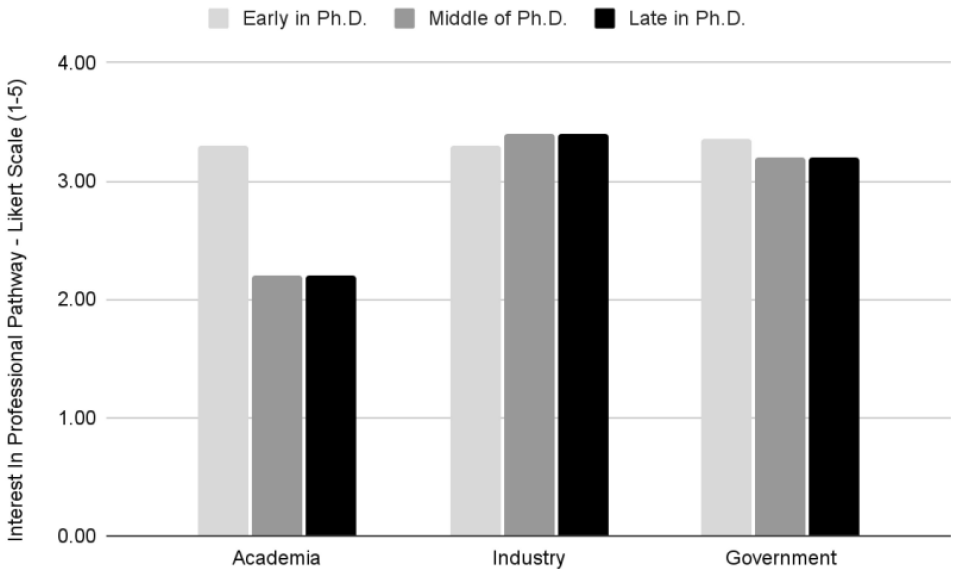

Fig. 2. Domestic Women Engineering Ph.D. Student's Professional Interests Over Time.

ment careers decreases slightly. Responses were on a 5 point Likert scale in which a lower response is related to a lower interest.

Table 5 summarizes the key survey differences by gender, graduation progression, and immigration status. For domestic students, early on in their studies there is a statistically significant difference between male and female students in terms of their satisfaction with their research which over time normalizes. Then during the middle stages of degree progression, domestic women become more open to considering "other" professional pathways while the interest of their male peers in academic positions is significantly higher.

Looking at the free-response survey items from engineering women, shows that there are changing perspectives among all career paths. For academia, there were some positive responses to explain their perspective for wanting to pursue an academic path:

> "The reason why I am interested in academia as I would have freedom to choose my research projects. As a graduate student, I hardly had the freedom, which was partly due to me, as I wasn't aware that I could apply for grants as an international student." (Computer Science, Senior level student)
>
> "My career plan is to seek a faculty position in a university. I like to research and also want to teach and serve people." (Material Science, Early level student)

But there were also some negative responses to explain why women engineering graduate students are no longer interested in an academic pathway:

> "I used to aim to be in academia, but then COVID happened, and I re-evaluated my goals." (Computer Science, Mid-level student)
>
> "Academia seems way too challenging with hardly any chance to have a life" (Electrical Engineering, Mid-level student)

Overall, this is consistent with what was found in

Table 5. Descriptive Statistics and Kruskal-Wallis Signed-Rank Test Results Comparing Male and Female Students

Categorization	**Life Satisfaction: Research Enjoyment**	**Career Interests: Industry**	**Career Interests: Other**	**Interest Change: Academia**
Whole Sample	4.01 (1.01)	3.57 (1.02)	0.34 (0.48)	3.00 (1.23)
Scale Range	1 (no) – 5 (yes)	1 (no) – 5 (yes)	0 (no) – 1 (yes)	1 (no) – 5 (yes)
Domestic students in early years				
Female	4.47 (0.62)			
Male	3.91 (0.79)			
Kruskal-Wallis Test	$p = 0.016$			
Domestic students in middle years				
Female			0.80 (0.41)	1.73 (0.70)
Male			0.31 (0.48)	2.63 (0.96)
Kruskal-Wallis Test			$p = 0.007$	$p = 0.0095$

the focus groups (discussed later) wherein students look at their advisor and the life they lead to assess if they want that for themselves. Another study cited this comparison as critical to their future pathway: "As doctoral students participate in practices of their research group, and observe their research supervisors in action, they form a prototype of a faculty member that represents their understandings of faculty work, and that they use to self-assess their suitability for faculty work" [23, p. 203]. Others have recognized a confidence difference between men and women in engineering as "role confidence" and a student's self-assessment of their ability to be successful in a role is predictive of attrition [6].

The free-response survey items for women engineering graduate students about industry careers shows both positive and negative perspectives as well:

> "After taking an internship in industry, I have decided to go the industry route after graduation." (Computer Science, Mid-level student)
>
> "Though the salary may be higher, I do not want to be bounded by the restraints of a company in choosing my research direction." (Mechanical Engineering, Early level student)

As for government roles, some students seek work at a government agency on science policy, while others indicate a negative experience. Finally, international students pointed out the limitations in going down this pathway; for many they see this as a closed door.

> "Current top-choice career path is in science policy, particularly in advocacy or advising policy either directly for an elected official or as part of a nonprofit group, government agency, or think tank." (Chemical Engineering, Mid-level student)
>
> "Experience with a prior government role influenced this answer - realized goals were more oriented towards impressing sponsor over solving problems." (Mechanical Engineering, Mid-level student)
>
> "I am an international student so scopes are narrow." (Electrical Engineering, Mid-level student)

4.1.2.3 Domestic vs International

Early on in their graduate careers, female, domestic students are significantly more satisfied with their progress on their research. As time goes on, this shifts to male students being slightly more satisfied with their research than their female counterparts (though not statistically significant at the 95% confidence level). While they end with similar satisfaction levels, one must question why female students' satisfaction with their research consistently decreases throughout their graduate studies. Towards the middle of their graduate career, likely around the time of working towards candidacy, female students are more likely to be interested in career paths other than those in the survey (academia, industry, government). Another study of master's students found that domestic and international students had similar motivations for enrolling in graduate studies as preparation for long term career goals [35]; however, the career options opened to domestic vs. international students upon program completion are not always the same and therefore impact students' plans and/or goals. International students, regardless of gender tend to be on the same page in regard to their interests, satisfactions, and support. The only significant difference is the interest early in their degree program to pursue a career in industry. Male students have a greater interest in industry careers at the onset of their time as a graduate student. It has been reported that international graduate students face challenges with visas and concerns for job placement post-graduation [36] as well as challenges with social integration and sense of belonging [37–38].

Comparing the same sex across international status reveals several differences in survey responses related to interest in careers in government and academic careers. Both domestic and international female graduate students reported that their interest in an academic career decreased over their time in their programs, but domestic students reported a significantly different decrease especially in their middle years. This could be as a result of differing views on qualifying exams or the demystifying of the academic career stresses.

Table 6 demonstrates the differences between domestic and international students at varying stages of academic progression; only the statistically significant differences between comparison groups are included in the table. For international students early in their degree programs, they indicate a lower interest in industry careers than their male counterparts.

Government roles were of generally low interest among both domestic and international women engineering Ph.D. students overall; however, there were differences. Domestic, female students started out with a higher interest in a government career than international, female students. The interest in government careers of domestic women decreases with time, while the interest of international women increases a bit throughout their program progression. Overall, female students experienced shifts in their interests in similar ways while domestic students reported them changing to a greater degree. There were not significant differences among their research, satisfaction, and support. As such these differences in career interest and their shifts, may be more cultural than specific to their programs or the university environment.

Table 6. Descriptive Statistics and Kruskal-Wallis Signed-Rank Test Results Comparing Male and Female International Students

Categorization	Life Satisfaction: Research Enjoyment	Career Interests: Industry	Career Interests: Other	Interest Change: Academia
Whole Sample	4.01 (1.01)	3.57 (1.02)	0.34 (0.48)	3.00 (1.23)
Scale Range	1 (no) – 5 (yes)	1 (no) – 5 (yes)	0 (no) – 1 (yes)	1 (no) – 5 (yes)
International students in early years				
Female		3.13 (0.83)		
Male		3.82 (0.90)		
Kruskal-Wallis Test		$p = 0.04$		

Note. Standard deviation is reported in parentheses.

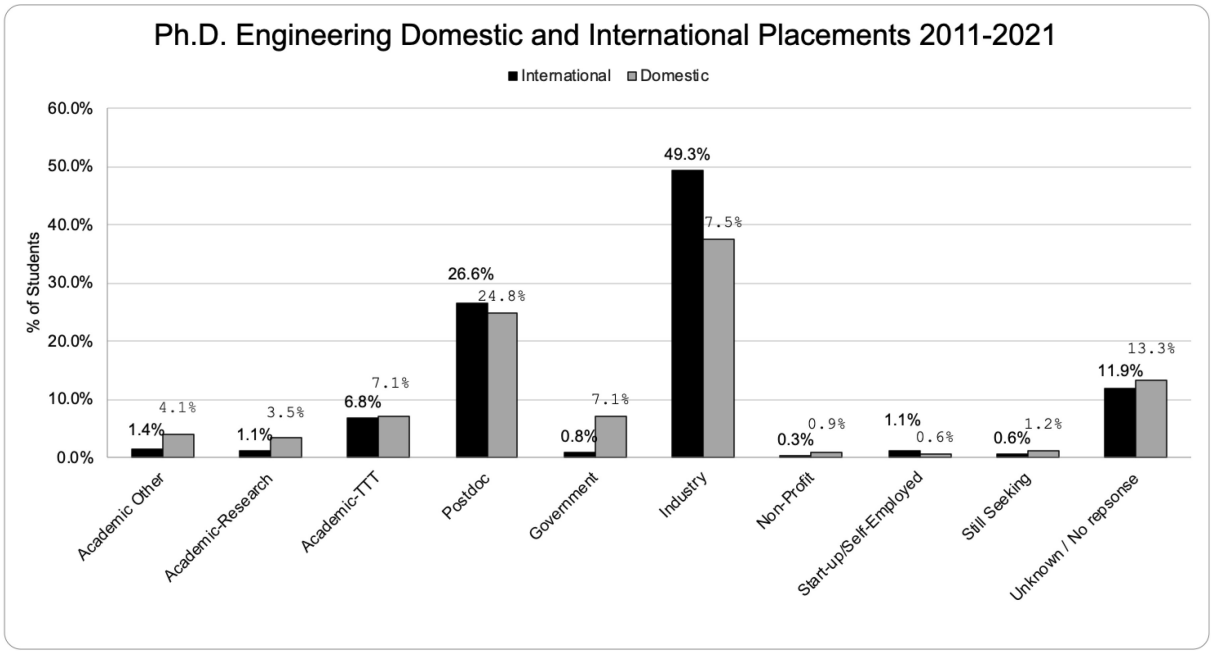

Fig. 3. Career Placements for Domestic and International Ph.D. Students from 2011–2021

Fig. 3 shows the career placements for domestic and international Ph.D. students over the past 10 years. According to an NSF report, about 10% of Ph.D.'s in engineering committed to academic positions (not including postdocs) which is comparable to the placements at institutions studied [39]. The biggest differences are that international students are much more likely to take industry roles and much less likely to take positions with the government. This mirrors the previous feedback provided from international students about the availability of government jobs. This also follows national trends, 1.5% of international students vs. 10% of domestic students take professional roles in government [40]. Additionally, in terms of academic pathways, international students are much less likely to take non-TTT, adjunct, or research positions than their domestic peers. Collectively, this shows that policies surrounding job access based on immigration requirements changes the professional pathways sought as it is not a gender difference.

4.1.3 Focus Group Results

There were two focus group discussions among women engineering Ph.D. students, (1) early in their academic pathway and (2) late in their academic pathway. A collective theme among both focus groups related to having an undergraduate mentor (peer or professor) that introduced them to the idea of going to graduate school. Most indicated participating in a research project helped them even consider a Ph.D. while some indicated a negative industry experience being a driving force towards graduate school. In talking to the women graduate students early in their studies, they articulated high positivity both in their research interests, support from their faculty advisors, and career possibilities. Further, the only barriers they see to completing their program related to completion of their technical work; they were not focused on other potential challenges. All early career graduate students indicated their biggest concern to be getting data they need for successful projects.

Several students identified themselves as in committed relationships with other graduate students and noted that the two-body problem could be a challenge. However, those problems were only minimally mentioned with most emphasis put on their actual research performance and outcomes as the major concern.

In contrast, the women graduate students that are nearing program completion, were much more subdued in their research interests. Each student indicated that their research interest had either stayed about the same or declined over the course of their studies. All these women indicated they liked their research well enough to complete the program but had other aspirations after graduation. The barriers to their career goals had little to do with research or completing work, but rather surrounding work/life balance, dual career concerns, or simply not wanting the life that their advisors live. They were somewhat in awe of all that their advisors were working on at any given time, and had drawn the conclusion that they wanted something different for themselves including not wanting to put off marriage, family, or kids to do one or more postdocs necessary to go forward in an academic career at a research focused institution. Using the Carnegie Classification [41], research focused institutions defined as R1's are doctoral granting institutions with very high research activity as compared to R2's which would have less emphasis on research. The advanced graduate students also expressed an enjoyment of teaching and working with students, but not wanting to devote themselves to the work / life that would entail so were considering R2s. They all said that what they see their advisors doing is "too much" and there is a clear identity piece to this understanding that they see others, including their advisor and research peers, that are either more talented, interested, or devoted to the research lifestyle. Another study by Smith and associates [42] suggested that to attract more women to STEM fields a shift in the underlying culture in STEM fields was needed to recognize more inclusive approaches to work in general. Prior studies have shown, women's perceptions (or mis-perceptions) of their effort level in comparison to others can negatively impact women in STEM in particular when there is already a stereotype that women lag behind men in scientific ability [42–43]. The advanced students said their faculty advisors were supportive, but not necessarily equipped to help with their long term non-academic plans, which coincided with the graduate's comment on the advisor as purely an advisor rather than a mentor in another study [37].

Non-domestic students were more likely to indicate plans to pursue a postdoc after completing their Ph.D. and indicated a long term interest in pursuing an academic research position. These students spoke about positions in academia as highly prestigious roles they hoped to achieve. But they also pointed out that non-residents are not eligible for positions in national labs or most government sponsored positions so they see their options as in academia or in industry (finding a company or university to sponsor them). The National Science Foundation shows temporary visa holders to be the highest percentage of postdocs [44].

5. Discussion

Returning to our research question: *How do graduate engineering students' career interests vary by sex, internationality, and academic level?*

The academic career interest level among women graduate students declined throughout their program progression. Collectively, universities across the country have a goal of diversifying their work force but have had limited gains [40]. Most diversity, equity, and inclusion efforts do not consider international students; in fact, even in retention studies the international status of students often means they aren't considered in retention metrics. This is a concern because international graduate students face many challenges for inclusivity and sense of belonging which is further exacerbated by the career limitations they face in terms of legal status and immigration policy [37]. Faculty and administrators should "care" about these factors as it likely impedes their productivity and achievement during their doctoral studies. The relationship between engineering graduate students and faculty members is critical to their "academic belongingness" [38].

The report from the National Academies of Science, Engineering, and Medicine [45] suggested that graduate students should be afforded professional discernment opportunities in industry, government, and academic sectors and we would agree. The challenge is that many faculty do not have experience beyond the academy and feel ill equipped to provide guidance on alternate pathways. This is especially critical because the numbers do not work for all engineering Ph.D. to be employed in a tenure-track faculty role; the supply exceeds the demand for that sector [22, 46]. An engineering faculty advisor is not expected to know about all of the opportunities for their graduate students; however, knowledge of the resources at the institution and beyond to support students' discernment and professional pathway are critical. For example, sponsoring students to attend

national career fairs and conferences would offer significant exposure to other opportunities (e.g., Society of Women Engineers, National Society of Black Engineers, Society of Hispanic Professional Engineers, in addition to the engineering professional societies for their discipline). Additionally, leveraging the university services for career preparations such as central or localized teams of career placement professionals to help prepare both a CV and a resume, cover letters, conduct practice interviews, and job searches would help a majority of graduate students.

Additional consideration must be given to how the COVID pandemic impacted current graduate students and their professional priorities. A study on this topic from LinkedIN reported that the fastest growing professional priority among job seekers was flexibility [47]. And further, people are placing a lower priority on work in general after the pandemic [48]. Finally, it's unclear if professional interests are also clouded by generational differences. Generation Y (birth years ~1980–2000), which many traditional graduate students are at the tail end of, have been reported to be motivated by workplaces with higher levels of autonomy [49]. It is possible that both the pandemic and generational priorities are also impacting students' professional priorities in ways that we have not yet seen. And as pointed out by Burt [23], a student's social comparisons to a "faculty prototype" are influential in professional decision making.

6. Conclusions

The current study was limited to a single institution that falls under the Carnegie Classification for an R1 institution and is a medium sized, Midwestern, Private institution. Future work should expand to other dissimilar institutions for increased generalizability. Despite these limitations, an important concern has been raised through this study: there is a degradation of academic career interest among women Ph.D. students throughout their program progression. All engineering graduate students consider multiple career pathways and as such should be afforded career discernment support for varied pathways and not just academia. In many instances, faculty advisors feel ill-equipped to advise students on professional pathways beyond their own in an academic setting, with a bias towards tenure/tenure track positions at primarily research institutions. While this does seem to align with the initial interest of women graduate students, it leaves options for industry, government, and service for students to explore without guidance. The students in this study reported concerns over the lifestyle and work-life balance demonstrated by their faculty advisors. But collectively, if the academy has a goal of diversifying the faculty at all institutions with more women and underrepresented minority faculty members, the career expectations and work / life balance need to shift and calls to question the current academic model surrounding recognition and promotion.

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