Analyzing the Experiences of Women in Engineering Research at The University of Virginia

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The University of Virginia (UVA) is one of the premiere public research institutions in the United States. UVA's engineering department is home to over 100 research labs, producing numerous publications each year in a wide variety of scientific fields in addition to educating and training the next generation of engineers. Yet, despite a commitment to "excellence through diversity" in their core values, only 31% of UVA's undergraduate engineering students are women, despite having a student undergraduate population that is 56% female (University of Virginia, 2019).

This is not abnormal. Across both academia and industry, women are consistently underrepresented in the fields of science, technology, engineering, and math (STEM). According to the World Economic Forum's Global Gender Gap Report, while women account for 49.3% of the global workforce, they make up only 29.2% of workers in STEM (Pal et al., 2023). Globally, women represent 25% or less of national science academies' fellows. In 2020, women comprised 19% of the United States' National Academy of Sciences, 25% of the Royal Society of Canada, and 10% of the United Kingdom's Royal Society (Malcom & Xin, 2021).

It has been shown that having diverse perspectives in engineering promotes innovation and creativity by capitalizing upon a wide range of lived experiences and backgrounds, tapping into a broader network for additional information, and avoiding the trap of groupthink. Put simply, when solving a problem, two heads are better than one, especially if each head has its own unique strengths, ideas, and opinions. However, for a diverse team to be successful, each member must feel welcome and valued by their peers, allowing them to express their individual ideas and the other members to consider these ideas critically. It is not enough for women to

simply be present in STEM spaces, they must be fully integrated into collaborative teams and not treated as "tokens" (Smith-Doerr et al., 2017).

It is important to have a diverse workforce in engineering research laboratories to ensure that problems affecting diverse populations are studied. Novel technologies and knowledge should benefit and represent the ideals of our diverse world– not just heterosexual, white men. It has long been argued that increasing women's access to education and careers in STEM will increase their representation (Rosser, 1998). Yet, despite having access to more opportunities in STEM than ever before, gender disparities persist at UVA and across the globe. This science, technology, and society (STS) thesis aims to develop specific strategies to increase the diversity, equity, and inclusion (DEI) of women in engineering research spaces at universities.

STS Framework

For my STS research, I used feminist theory as a framework to analyze and contextualize the experiences of women in engineering. Feminism is defined as the "belief in and advocacy of the political, economic, and social equality of the sexes" (Merriam-Webster, n.d.). Overall, feminist theory is a framework that studies how to elucidate how to disrupt power structures to incur changes that promote the equality of women and men (Arinder, 2020). However, feminism and feminist theory are complex schools of thought with numerous branches and four "waves" from the early 1850s to present day (Rampton, 2008).

In the late 2010s, the portmanteau "STEMinism" combining STEM and feminism grew in prominence– giving a title to the belief in equality of the sexes specifically within STEM fields (Patrizio, 2023). STEMinism draws upon several core tenets of fourth wave feminism: it

utilizes the Internet to promote global dissemination of knowledge, it supports the rights and equality not just of women but also nonbinary individuals, and it acknowledges the importance of intersectionality within feminism. For clarity and brevity, throughout this thesis, the use of the terms "women" and "female" will be used interchangeably and also to refer to the umbrella of femme, nonbinary, and third-gender individuals– essentially anyone who is not a man.

Many programs designed to increase the recruitment and retention of women in STEM are not developed by feminist scholars and thinkers, and feminist theory doesn't provide a singular, unified framework for the analysis of these programs (Rosser, 1998). One reason for this is that women cannot be treated as a singular, unified entity with a "one-size-fits-all" strategy to improve their representation within STEM. For the purposes of this STS thesis, I will focus on three main tenets of feminist theory for my framework analysis, primarily derived from the mission statement of the organization "Steminists.org" (Garg, 2023).

The first core tenet of feminist theory is that in order for women to gain equal rights in all spheres, they must have equal representation in all spheres. STEM fields have been traditionally dominated by men and scientific laboratories are often regarded as "boy's clubs." Many young women are not even aware of educational or career opportunities available to them because they have never seen a woman pursuing them before. One study found that in the early twentieth century, the presence of a female physician in a rural town increased the likelihood that a young woman would choose to pursue an education in STEM by 5% (Bleemer, 2016). In addition to exposure to potential careers, having female role models in STEM challenges hierarchies of knowledge by providing advice and gives girls concrete examples of women defying negative stereotypes and persevering despite obstacles (Johnston, 2019).

The need for representation is even more crucial for women who exist at the intersection of multiple marginalized identities, such as race or sexual orientation. Intersectionality, coined in 1993 by Kimberlé Crenshaw, is a term used to describe how the experiences of individuals within several underrepresented groups cannot be described simply as a combination of oppressions (Crenshaw, 1993). In order to create an equitable environment in engineering for all women, the unique experiences of women of a variety of races, religions, ethnicities, national origins, sexual orientations, and (dis)abilities must be actively considered and represented.

The second core tenet of feminist theory is that there is no one right way to be a woman. Gender is a social construct, and by attributing certain behavioral or personality traits to individuals with XX or XY chromosomes, society creates dangerous and damaging stereotypes of what is “masculine” or “feminine.” In David Chambers' landmark 1983 study, when over 4,800 children between the ages of five and eleven were asked to simply “draw a scientist,” only 28 drew women (Chambers, 1983). This study indicates how children are raised to identify characteristics associated with science– objectivity, rationality, and decreased emotion– with men rather than with women.

To this day, many women feel pressured to behave in a more “masculine” manner to be taken seriously in their career or academics. Historically, women were discouraged from pursuing careers in STEM because they were perceived as being incompatible with goals of having a family or being a wife (Johnston, 2019). Feminism aims to increase young women’s confidence in themselves and their capabilities in any field they pursue– including STEM. By redefining what a scientist “should” look like and eliminating the dichotomy between having feminine attributes and being a successful professional, women will not only have increased DEI

in engineering, but will also be able to pursue their goals without being forced to perform in a way that the patriarchy dictates.

Finally, the third core tenet of feminist theory is that hegemonic cultural practices that oppress women must be abolished. STEM is dominated by Euro-centric, white, male views of what qualifies as science and who qualifies as a scientist. Instead of forcing women to assimilate into existing structures that uphold their subjugation, scientific fields must be restructured to make room for new insights specifically from women. In the words of Heybach and Pickup, science is not "a commodity to be equitably distributed across gender lines," but rather is "a domain of knowledge impacted by the experiences of gender itself" (Heybach & Pickup, 2017).

Increasing the DEI of women in STEM is not simply a matter of integrating more women into existing STEM spaces and forcing their conformity within patriarchal structures– a practice that is referred to as "painting STEM pink." It is a matter of honoring and incorporating the unique perspectives and lived knowledge of women and appreciating them within scientific practices (Roy, 2024). By combining feminism and STEM, the goal is to challenge the societal perceptions of science and broaden the definition of scientifically valuable information to include socially constructed knowledge (Rosser, 1998).

Case Context

I focused my STS research on the experiences of women in engineering research at UVA across the following departments: biomedical engineering (BME), chemical engineering (ChemE), civil engineering, computer engineering, computer science, electrical and computer engineering, material science engineering, mechanical and aerospace engineering, and systems

engineering. I analyzed the experiences of women at the undergraduate, Master's, PhD, post-doctoral, and faculty levels across a variety of research experiences.

I opted to focus on UVA engineering because it is an expansive research community but also is more narrow than all STEM related research. Moreover, my own experiences as a woman engineer in research at UVA gave me a certain amount of insider knowledge and the respect of peers within this organization. My connections within the engineering research community to both undergraduate and graduate students allowed me to cast a wide net for surveying, particularly within the BME and ChemE departments.

Research Question and Methods

Through my STS research, I investigated the experiences of women in engineering research at the UVA to answer the question: how can universities increase the equity, diversity, and inclusion of women into engineering research?

I conducted an anonymous online survey through the UVA affiliated website Qualtrics. I distributed the survey via the Society of Women Engineers GroupMe, through the engineering sorority Alpha Omega Epsilon chapter at UVA, and through additional contacts I had across various engineering departments. In addition, I had graduate student members of my research lab in the BME and ChemE departments distribute the survey to contacts in their respective departments. Only individuals with a UVA email address could complete the survey.

Qualtrics provided data analysis tools that allowed me to filter through the responses and provided me with mean, standard deviation, and variance calculations for all quantitative data.

All additional data analysis completed, including statistical analysis, and all figures created were done with Microsoft Excel.

I received 85 responses to the survey, with 96.5% of participants identifying as female, 2.4% of participants identifying as nonbinary/third gender, and 1.2% of participants identifying as other. Male responses were excluded from data analysis. Participants were 55.3% graduate students, 43.5% undergraduate students, and 1.2% faculty members. After collecting demographic data and the participant's year of study and major, the survey split into two separate tracks based on participant responses: those who had participated in engineering research at UVA (72.9%) and those who had not (27.1%). The two tracks were analyzed separately.

To assess the role of intersectionality throughout the data, I categorized survey participants into four groups: LGBTQ+, white participants; heterosexual, non-white participants; LGBTQ+, non-white participants; and heterosexual, white participants. I defined these categories in regards to gender or sexual orientation as anyone who selected nonbinary/third gender or other when asked to specify their gender identity or as anyone who selected any option other than straight/heterosexual when asked to specify their sexual orientation. I defined these categories in regards to ethnicity or race as anyone who selected "yes" when asked if they identified as Hispanic, Latinx, or of Spanish Origin or as anyone who selected any option other than only white when asked to specify their race.

Results

Overall, respondents who had participated in engineering research at UVA had generally positive attitudes towards their experiences. However, several distinct themes emerged when

participants were asked to give specific positive and negative examples of actions UVA has taken to impact their experience as a female engineering researcher. The two most commonly cited positive actions UVA has taken were the positive culture created by other female engineering students and individuals having supportive faculty advisors. The two most commonly cited examples of things UVA could improve upon were to hire more diverse professors and to establish a clearer reporting system for instances of gender-based violence, harassment, or discrimination.

For respondents who had not participated in engineering research at UVA, 69.6% were interested in participating in research in the future while 21.7% were not interested and 8.7% gave no response. The two most commonly cited reasons for why respondents who were interested but had not yet participated in research were a lack of awareness of research opportunities and impostor syndrome.

Respondents Who Had Participated in Research

Of the 85 total survey responses, 60% of respondents had participated in engineering research at UVA and filled out the entirety of the survey. The bulk of the survey had participants classify a set of 15 statements (listed in Appendix 1) along a Likert scale and their responses were categorized numerically and totaled. The minimum total response was 15 and the maximum total response was 75, with a higher number correlating to a more positive response. The mean total response was 58.333, with the lowest total response being 37 and the highest total response being 72. When plotted as a histogram, shown in Figure 1**,** the data has a left skew, indicating more positive responses than negative.

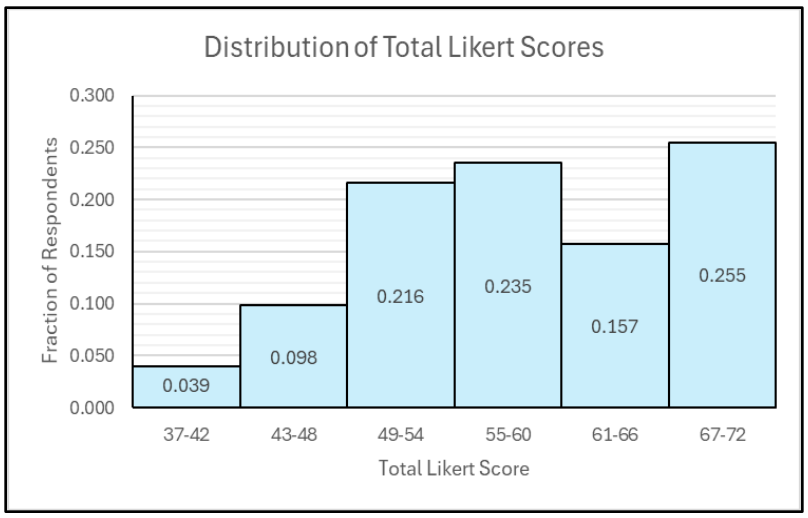

Figure 1. Distribution of total Likert scores

The statements with the two highest average responses were "I feel welcomed, valued, and included by my female peers at UVA" at 4.608 and "I feel welcomed, valued, and included by my mentors and superiors at UVA" at 4.373. This aligns with the qualitative responses to the later questions in the survey: participants consistently mentioned a supportive culture among female peers within their departments, the importance of women supporting other women in STEM, and the positive role that their mentors had in their STEM careers. One participant said, "I feel like a lot of the initiatives that have had a positive impact on me as a women (sic) in engineering at UVA were started by my peers and were predominately (sic) run by students." Several graduate student participants spoke highly of their advisors, with statements including, "my advisor has been very accepting and incredibly (sic) to work with," "I have found support from my advisor," and "our department chair and my PI are brilliant women scientists!" These statements align with feminist theory's emphasis upon representation of women in STEM, specifically the importance of female role models (Johnston, 2019).

The two statements with the lowest average responses were “I believe UVA treats all of its engineering researchers with fairness, regardless of their racial and cultural background, national origin, religion, sexual orientation, and status of pregnancy or parenthood.” at 3.471 and “I believe UVA would take appropriate action if an instance of gender-based violence, harassment, or discrimination was reported” at 3.529. This was also supported by qualitative data, as several participants expressed disdain for the lack of diverse faculty in their departments and for the reporting and disciplinary systems currently in place within UVA engineering. Participants said, “hopefully with years it will get better, but I feel like a lot of the… younger staff seems to have more equal hiring practices” and “[UVA should have] more initiatives to recruit more diverse faculty and graduate students.” This also falls under the category of the need for equal representation within the feminist theory framework, particularly the need for intersectional representation (Crenshaw, 1993).

In regards to the reporting system, one participant said, “for each department, there should be an intermediate between reporting to Title IX and having an issue swept under the rug. Most people won't want to report to Title IX because they believe it's ‘not that serious.’ JRI [Just Report It] gives the impression of only regarding violence-based reports.” Other suggestions that participants had to improve their experiences in engineering research as women included implementing gender neutral bathrooms in research facilities, adopting “better childcare options and maternity leave,” and “more seminars and training for the faculty to promote DEI.” These all align with the feminist core tenet that patriarchal structures and practices that oppress women must be abolished (Heybach & Pickup, 2017).

These suggestions expanded beyond just aiming to achieve gender equality, but equity across a variety of diverse cultures, races, sexualities, and other categories. This prompted me to

look at the survey data across different demographic groups, and distinct differences emerged. LGBTQ+, non-white participants had a drastically lower average total response than any other demographic group of 50.571. Displaying the data points in a box-and-whisker plot shows the discrepancies between the demographic categories (shown in Figure 2) and the data is further represented in Appendix 2. Statistical analysis was completed on the Likert scores in the form of a single factor ANOVA test and a Tukey post hoc test to compare the values across four different demographic groups. The tests found that there was a significant difference (p=0.1) between the mean Likert scores for heterosexual, white participants and LGBTQ+, non-white participants and heterosexual, non-white participants and LGBTQ+, non-white participants. The differences between all other demographic group pairings were not found to be statistically significant. These findings further support the importance of Crenshaw's theory of intersectionality within feminism (Crenshaw, 1993).

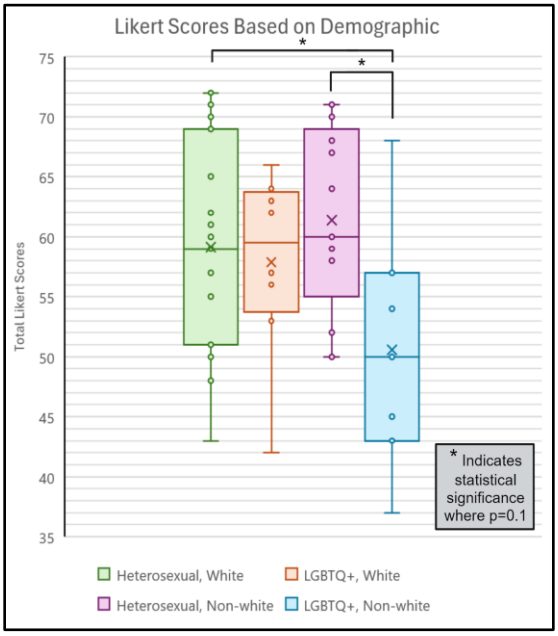

Figure 2. Total Likert scores based on participant demographic where * indicates statistical significance between groups where p=0.1

Respondents Who Had Not Participated in Research

Among survey respondents who are interested in pursuing research in the future but had not yet, there were two main reasons cited for why they had not participated in research yet. First, over 25% of respondents stated that they were unaware of research opportunities in their major or how to go about becoming involved in research. This is a problem with a relatively easy solution– in the digital age, developing and implementing a centralized way to communicate research openings for undergraduate students and the corresponding time commitments, expectations, and prerequisites would be as simple as someone maintaining a Canvas or Piazza page with a series of Excel spreadsheets. In addition, the implementation of a mentorship program between younger and older students could be a valuable way to increase underclassmen awareness of research opportunities, further highlighting the significance of representation and role models for women in STEM (Johnston, 2019).

The second most commonly reported reason for not yet participating in research was impostor syndrome– participants cited a "fear of rejection" or hadn't pursued research due to "not totally knowing if I would belong in a lab at all." This is a problem that has a more complex solution. Impostor syndrome, a term first coined in 1978, describes feelings of self-doubt or that one is a non-deserving professional, and has an extensive role in academia (Clance & Imes, 1978). Impostor syndrome has been found to be particularly prevalent among women, which could be attributed to negative stereotypes surrounding women's intelligence or capabilities in STEM fields.

Discussion

Listening to the experiences of women in engineering research is the first step to creating a more equitable academic environment for all. Despite being a woman in engineering research myself, by broadening my perspectives and listening to what other women have to say, I have gained a more nuanced idea of obstacles that exist for women from backgrounds different from my own. By analyzing the results of the survey using feminist theory as my STS framework, I have elucidated several strategies that universities can employ to improve the DEI of women in engineering research.

First, universities should establish mentorship programs to connect young women with older women in their fields of study. Some majors or other organizations at UVA have mentorship programs currently in place (for example, the BMEConnect program launched this past year in the BME major), but increasing the number and accessibility of these programs should be a major goal of universities overall. By connecting female undergraduate students to female graduate students and alumna, they will gain knowledge of new opportunities that they were previously unaware of, learn strategies and advice for navigating STEM as a woman, and will be able to develop mutually beneficial relationships (Johnston, 2019). In addition, for the 25% of survey respondents who were interested in pursuing research in the future but had not yet, a mentor could help them get involved in research.

Second, universities should seek to actively recruit and promote faculty and students from a variety of cultural and gender backgrounds. Currently, only 23.6% of engineering faculty are women, as shown in Figure 3.

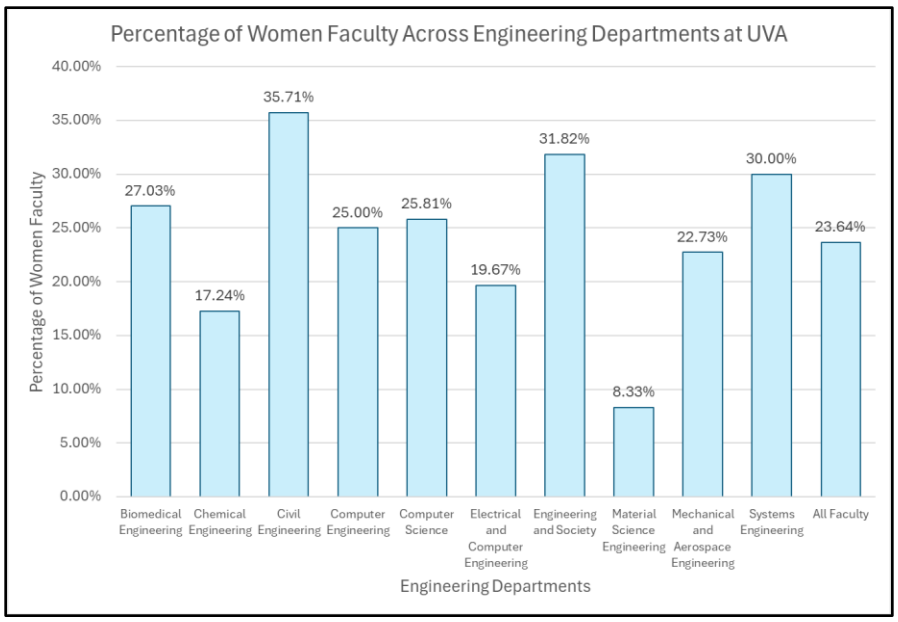

Figure 3. Percentage of Female Engineering Faculty by Department at the University of Virginia

By hiring professors and recruiting students with a wide range of lived experiences, universities can increase the amount of collective knowledge in the university community, provide representation (and potential mentors and role models) for students from diverse backgrounds, and shape the future of their departments by bringing new perspectives into university decision making regarding professor salaries, tenure, and promotions. One specific action that universities can take to accomplish this goal is to employ a DEI committee of existing students and professors for hiring faculty and recruiting students. Building upon this strategy, universities must acknowledge the importance of intersectionality within their hiring and recruiting practices. From Kimberlé Crenshaw's TED Talk, the first step in minimizing oppression due to intersectionality is to "bear witness to the often painful realities that we would just rather not confront" (Crenshaw, 2016).

Third, universities must abolish structures and practices that oppress women and other minorities. One specific way that universities can achieve this is by adopting a no-tolerance policy towards gender-based violence or harassment and establishing clear, well-communicated methods for reporting such violence or harassment. Within the goal of abolishing structures that oppress women, university officials must actively listen to the needs and concerns of their female students (Roy, 2024). To do this, continuous, open lines of communication between students, professors, and administrators must be established. One way that UVA currently accomplishes this is by having administration hold open office hours for students or professors to attend.

Fourth, universities should seek to decrease students' impostor syndrome in order to make them feel that they belong in STEM. Impostor syndrome is a term used to describe the tendency of individuals to diminish or discount their own intellectual abilities despite evidence proving otherwise (Price, 2013). Impostor syndrome is especially prevalent among women and in underrepresented racial and ethnic minorities (Chrousos & Mentis, 2020; Collins et al., 2020). One of the ways to begin to combat impostor syndrome is to normalize it within academic settings, increasing its visibility by talking about it. In addition to this, another strategy for remedying impostor syndrome is reframing one's thoughts in logic (Young, 2017). Impostor syndrome should be discussed in all introductory engineering courses so young women can learn that it is normal and it should not be a barrier to their success in STEM.

Limitations and Future Directions

This survey is not an exhaustive look into women's attitudes towards engineering academia at UVA, but it attempts to capture a snapshot of these. One of the main limitations of

my STS research is the amount of survey responses. I was pleased to get 85 responses, but only 51 people completed the entire survey, and of those responses, the vast majority were BME majors (Figure 4). I was aiming to do more analysis of specific majors within UVA, but there was not enough variety of majors among respondents to do so. In addition, my analysis of survey responses based on participant demographics was limited by the fact that the number of respondents in each category varied, with 23 heterosexual, white participants and only 7 LGBTQ+, non-white participants. Due to the limitation of sample size, I used a p-value of 0.1 for statistical testing.

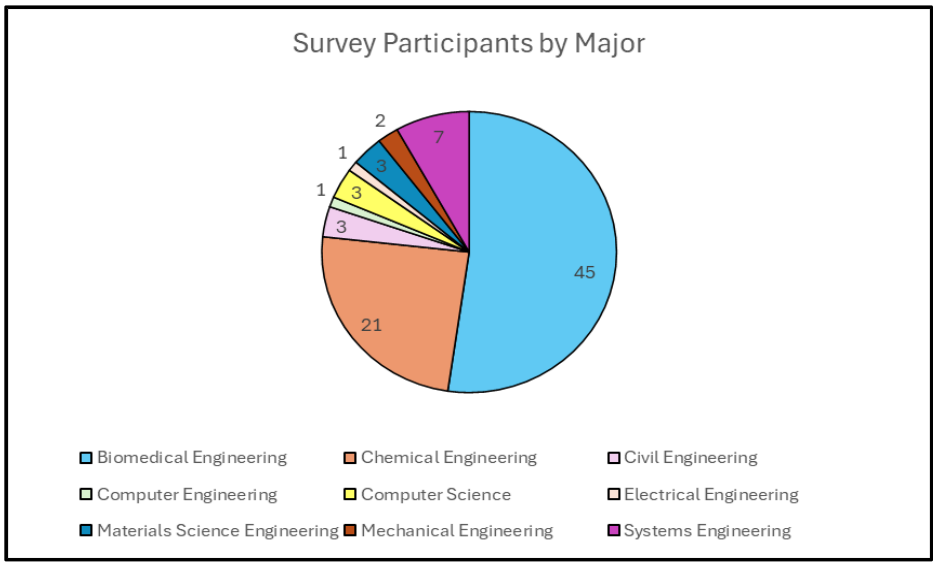

Figure 4. Survey participants by major

If I were to redo my STS research, I would have specifically targeted this survey to a wider variety of participant majors and demographic backgrounds. I would also be interested in seeing how the opinions and experiences of women in engineering change over time as generational ideologies change and hiring practices at UVA adapt.

I aim to take this STS research with me throughout the remainder of my career in research and academia. I have just committed to a BME PhD program, and I hope to one day become the principal investigator of my own lab. In doing so, I aim to create an environment that is welcoming and equitable for researchers of all backgrounds. From personal experience, I know that having a research environment where you feel valued and supported makes it considerably easier to meet your scientific goals as an engineer. By fostering an inclusive environment in my own future lab, I hope to nurture scientific minds of the future and be a resource and advocate for graduate and undergraduate engineering students as they navigate the world of academia.

Conclusion

My goals in conducting this STS research were to shed light on existing challenges for female engineering researchers and to strategize ways to combat them. By establishing mentorship programs, recruiting diverse faculty and students, abolishing existing oppressive practices, and raising awareness about impostor syndrome in introductory STEM courses, universities can work towards building equitable engineering research programs that benefit all of their students and professors, regardless of their gender, race, ethnicity, sexuality, or any other demographic.

Many initiatives that aim to increase the access of women in STEM seek to simply integrate women into existing patriarchal structures, but by reorganizing their research departments and working to change the landscape of STEM education and research as a whole, universities can create academic spaces where women feel valued and included. By outlining

ways in which UVA and other universities can create more inclusive environments for women in engineering, I hope to not only promote innovation and creativity by capitalizing upon a wide range of lived experiences and backgrounds, but to help pave a path for a more equitable future of academia for all.

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Appendix 1: Survey Statements

Participants were asked to respond to each statement with either strongly agree (corresponding to 5), somewhat agree (corresponding to 4), neither agree nor disagree (corresponding to 3), somewhat disagree (corresponding to 2), or strongly disagree (corresponding to 1): How would you describe your personal experience in engineering research at UVA in the following categories?

1. I feel welcomed, valued, and included by my female peers at UVA.
2. I feel welcomed, valued, and included by my male peers at UVA.
3. I feel welcomed, valued, and included by my mentors and superiors within my department at UVA.
4. I feel welcomed, valued, and included by UVA as a whole.
5. I feel comfortable discussing diversity and inclusion with my colleagues and superiors at UVA.
6. I believe UVA treats all of its engineering researchers with fairness, regardless of their gender.
7. I believe UVA treats all of its engineering researchers with fairness, regardless of their racial and cultural background, national origin, religion, sexual orientation, and status of pregnancy or parenthood.
8. I believe UVA would take appropriate action if an instance of gender-based violence, harassment, or discrimination was reported.
9. As a part of UVA, I feel I can achieve success as my authentic self.

Participants were asked to respond to each statement with either far better (corresponding to 5), somewhat better (corresponding to 4), about the same (corresponding to 3), somewhat worse (corresponding to 2), or far worse (corresponding to 1): How would you compare the University of Virginia to other universities in the United States in the following categories?

10. Commitment to engineering research.
11. Commitment to engineering education.
12. Commitment to diversity, equity, and inclusion in engineering.
13. Commitment to gender equality and equity in engineering.
14. Commitment to diversity, equity, and inclusion in university leadership and faculty.
15. Commitment to gender equality and equity in university leadership and faculty.

Appendix 2: Supplemental Quantitative Survey Data

Table 1. Likert Score Data Across Demographics

	Heterosexual, White	LGBTQ+, White	Heterosexual, Non-white	LGBTQ+, Non-white	All Participants
Number of responses:	23	8	13	7	51
Minimum response:	43	42	50	37	37
Maximum response:	72	66	71	68	72
Average response:	59.130	57.875	61.385	50.571	58.333
Standard Deviation:	9.117	7.809	10.245	7.741	9.125
Variance:	83.119	60.982	104.952	59.923	83.267