Qualitative Study of Women's Personal Experiences of Retention and Attrition in Undergraduate Engineering Programs

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INTRODUCTION

Women's continued underrepresentation in the field of engineering should continue to be of national priority. From 1997 to 2016, the proportion of women earning degrees in engineering has increased from 18% to 21% [2], [3]. This 3% growth over a nearly two-decade period is indicative of larger social issues among institutions regarding women and other marginalized students [4]. This observed lack of women and racial minority representation in STEM degree attainment ultimately impacts representation in professional fields, which could lead to increased gender and racial labor market inequality [4]. Minority retention research in engineering education spaces is conducted to increase STEM graduation rates, which could be used as a tool in socioeconomic mobility for minority members [5].

This work in progress paper presents the preliminary results of a qualitative research and analysis project conducted with the goal of addressing the following research questions:

(1) What behaviors are related to retention and attrition amongst undergraduate women in engineering?
(2) How do perceptions of the undergraduate engineering education ecosystem compare amongst various women in the major?
(3) Which experiences in this context are most meaningful to their achievement motivation in the field?
The first question in this research was assessed in a prior study and isn't the main focus of the project[6].

An overarching goal of this study is to advance researchers' understanding of women's underrepresentation in the field of engineering. Additionally, to discover what factors influence educational outcomes in ways that align with the current sociocultural lens of engineering education. Lastly, this research adds to the discourse in engineering education as it pertains to women and intersectional underrepresented racial and ethnic minorities. The paper supports the call to transform formal learning environments and kairotic spaces to be more equitable and inclusive of all students with underrepresented minority identities[7].

LITERATURE REVIEW

Previous studies regarding women in engineering have provided a robust breadth of explanations for attrition rates amongst women and underrepresented racial and ethnic minority students. These explanations include sociocultural resources such as family income and academic preparation. Problems akin to these, if appropriately addressed and improved, could help increase the retention of STEM degree attainment for every group [4]. Multiple theories and models deduce the factors associated with retention, success and learning [9]-[12]. Numerous previous studies have used an Input-Environment-Output model, which uses students'

sociocultural and personal background characteristics (sex, race, gender, values) to better understand how students interact with faculty and peers within an academic institution. From these studies, it was demonstrated that students' engagement in curricular and co-curricular experiences with their peers and faculty has an impact on their general success and ability to learn. Within the context of undergraduate engineering education, original personal differentiated academic outcomes and experiences exist based on one's race and gender identity[13]-[15].

In addition, prior studies have given confirmation of multiple other factors that affect student attrition. Attrition from STEM related majors reaches an apex at around six semesters of study [7], and between the binary gender, female students have a higher probability of withdrawing from their major then their male counterparts [8], [4]. Non-Asian underrepresented racial/ethnic minority students have the highest probability of major attrition in comparison to their White and Asian counterparts [4], [7], [8], [16]. These racial/ethnic minority students, even after persisting past the average major attrition period of students in STEM, are more likely to withdraw from their major after eight semesters of study [4] and are less likely to attain their degree within five years compared to White students [5]. Although there is underrepresentation of women and non-Asian minorities, Black women are more likely than White women to enter STEM, but Black women are also less likely to graduate than their White counterparts [4].

A comprehensive research investigation of learning and success in undergraduate engineering education must address specific issues of environmental integration, perception of the self, academic characteristics, and background characteristics. A study of this nature must be conducted with ideas of personal success in the engineering education environment as well. Academic success is often associated with the ability to graduate or retain a major, though these factors may not be how the students measure their own success[17]. Research of this nature would have to aim to be inclusive of a diversity of student’s thoughts, ideas, values, and opinions to express their learning and success impacts.

METHODOLOGY

As the main author of this work, before beginning to explain my methodology, it’s important to engage in a reflexive approach to the research and recognize how the positionality of my identity influences the creation of the research. Elle Kreiner, first author, is a queer, neurodivergent, disabled, nonbinary, White identifying person. They live in their home county of Baltimore with their pets and friends. Elle Kreiner has a Bachelors in Cultural Anthropology and Sociology, as well as a post-baccalaureate certificate (PBC) in the Nonprofit Sector all from University of Maryland, Baltimore County (UMBC). In addition they will have completed their Masters in Applied Sociology and two additional PBCs in the Social Dimensions of Health and Applied Social Research Methods in late May of 2023 also from UMBC. This positionality statement is used to not only engage in a reflexivity, but to recognize the impact of the author's identity on ontological and epistemological research practices [1].

This work is currently in phase two of three total phases: phase one included quantitative data collection and analyses, phase two is composed of qualitative data collection and analyses, and stage three co data integration and aggregation. During phase one data research, previous

researchers suggested that participants would be recruited experientially, based on various individualized, but still commonplace, academic events (transferring into a university rather than matriculating at freshman placement, major swapping behavior). Shortly following the inception of the qualitative portion of this study, recognition of the impossibility of that methodology came to fruition. Experiential based focus groups couldn't be completed for multiple reasons, with the foremost being that the researchers didn't yet know the lived experiences of the students. The examples of major switching, or transferring in were provided, but it can be deduced that there is no way to be all encompassing of lived experiences without knowing what those experiences are. A heuristic phenomenological approach to the research design was conducted to elucidate the lived experiences of women who pursue undergraduate degrees in engineering. The research pivoted to separate the participants by engineering major and complete one-on-one interviews instead when it was recognized that the experiential approach to conducting focus groups was nonviable.

UMBC, the university at which the study was conducted, has three specific engineering majors: chemical, computer, and mechanical engineering. With the goal of obtaining a diverse and representative pool of respondents, the study used a population of 14 cohorts of women: alumna from 2006 to 2016, and currently enrolled undergraduate students at a mid-sized public research university in the Mid-Atlantic region of the United States. Using this style of purposive selection was essential for the rigor of the collected data [18]. Prior to the beginning of data collection this project was submitted and approved by the UMBC Institutional Review Board.

Sampling was conducted from September 2022 to January 2023. Current undergraduate women were contacted originally in groups of ten and then eventually as full cohorts of students in each individualized major. Every current female undergraduate student in all three engineering majors was contacted about their participation in the study. In total, thirty-one undergraduate women engineering students responded to the Google Form that was dispersed through email. A goal of 25 to 30 interviews was set to reach saturation, making for an effective first round of undergraduate participant recruitment.

Alumna recruitment consisted of a two-pronged effort to engage alumna in scholarships about their previous institution. Initially the only contact information that was given for the alumna was their previous institutional emails, many of which, it was assumed, were not being used any longer. This first set of institutional emails rendered a little over 900 data points. After using names to search for LinkedIn Profiles and attempting to build rapport with alumna through 299 character connection requests, it was rationalized just how difficult the task at hand was. After review and alumna network searching, around 275 alumna data points were collected, all containing original non-institutional-affiliated emails. Subsequently, one large email was dispersed to every contact on that list, generating 33 responses to a Google form about participation, along with many people who did not fit the requirements of the study, but wanted to assist however they could.

Prior to being accepted into the study, participants were asked to respond to the aforementioned Google Form. This form was used to collect objective background information on the student or alumna's academic or institutional identity. Questions are all-encompassing and representative of all possible responses from students. Examples of undergraduate questions

included asking the participants' major, credit amount, scholarship affiliation, and on-campus student group involvement. Examples of alumna questions had included asking their current position and undergraduate scholarship. Additionally, questions to garner comfort were asked to both groups, such as the participants preferred name, preferred interview style (one-on-one or focus group), and if they had any questions even before agreeing to participate. This Google form was effectively used to gather academic identifiers so that the substantial interview procedures could hone into personal experiences, rather than be fraught with non-descriptive questions and answers.

Participant recruitment was a slow process when it began, gaining traction overtime along with the growth in the understanding of participant's wants and needs from the study. It was recognized early that for the study to be successful, the methodology had to adapt, an iterative process was used. The first focus group, composed of two female students in the chemical engineering (CHEME) department, led the researchers to consider a previously unseen dimension: that the experiences of the women were sensitive, and best expressed in a private one-on-one setting. It was rationalized that women were uncomfortable with focus groups, because even though they had the identifying factor of being female, certain facets, both natural to the engineering disciplines and internalized, created discomfort sharing with peers. A suspected factor was the competitive nature of the engineering education space. There is also a persistent fear that students will be seen as "not cut out for" or unsuited for an education in engineering [19]. Some other fears were explicitly mentioned by original participants. Some examples include the fear of backlash from the department or its professors and gossip or altered reputation amongst the cohort. Additionally, students who have other intersecting minority identities of race, ethnicity, or ability, typically have personal experiences that differ greatly from their White and/or able-bodied counterparts [20]. Many students in the engineering spaces at this university have intersectional identities, making it pertinent to explore those individual identities and how they impact undergraduate engineering education as an intersection rather than a group.

Having taken the gathered information into consideration, the participant recruitment was adjusted to clarify that one-on-one interviews were also being conducted, which had substantially increased participation. The aforementioned focus group had been the only one conducted. The other participants' data was gathered through 30 to 60 minute, semi-structured, one-on-one interviews. In total, we have had 21 students participate in interviews. Semi-structured interviews were chosen over structured interviews to give the researcher flexibility to explore new questions while maintaining the use of a structured set of questions on multiple topics[18]. Question sets varied minimally between alumna and undergraduate students, and followed a strict guideline to develop topics in the participants background, role models, interactional support, discriminative experiences, impacts and education. Most of these topics had two to three questions listed under them, in which the interviewer would pick one or two in each topic category to discuss, leading to a total of around five to seven questions per interview. The semi-structured style was further used to obtain diverse answers, and to iteratively improve each interview. An intersectional approach was used throughout the study, especially in the creation of interview questions. Questions were adapted to be considerate of multiple culturally ascribed identities.

Interviews were conducted over a common virtual face-to-face platform similar to Zoom that is known as Webex. The interviews were recorded in both visual and audio, with the visual portion being deleted immediately following successful transcription of the interview. All data was disinfected of personal identifiable information and every participant was given a pseudonym. Interview title and data were recorded using an alpha-numeric 17-digit coding system to organize them. With significant measures put in place to anonymize the data and delete all personal identifiable information, more alumnae were willing to participate, knowing their opinion on the undergraduate program would not be connected to their names. Following the successful collection of a few data points, analysis began.

Qualitative analysis of the interview transcriptions was conducted longitudinally, continuing throughout the duration of the study. The qualitative software Nvivo was used to categorize themes, subthemes, and other pertinent data points in the original interview transcripts. In the data analysis, particular care was given to contextualization to better be able to differentiate reasons for phenomena. Subsequently, these themes were connected through common analysis pattern recognition.

FINDINGS

"*Here's my problem with people in science; I feel like you could tell them everything, but what's going to make them actually change?*"

-Jasmine, Mechanical Engineering '24

Perceptions of the undergraduate engineering education ecosystem varied widely amongst the women throughout the chemical, computer, and mechanical engineering disciplines in College of Engineering and Information Technology (COEIT). This variation was influenced by specific identifying factors and experiences tied to each major.

The student's personal positionality, their race, ethnicity, and other culturally ascribed traits had influence on their interpretation of their environment. Attention was given to students with intersecting identities to better understand what pieces of their identity influenced their experiences. Following the elucidation of these perceptions of the ecosystem, more specific personal experiences were collected and studied to find meaning towards the student's motivation to achieve in the field. Ultimately, the core findings were that women students have a variety of experiences, but also cohort-wide experiences, and class-wide experiences that assisted in the creation of their perceptions. These findings will cover the overarching perceptions and experiences with adversity that women experience in the engineering environment. The findings will also provide experiences of development that have been meaningful in women's achievement motivation.

Multiple women in the study expressed dealing with forms of gender and or racial discrimination within STEM, imposter syndrome, and feelings of loneliness as they continue to matriculate through the program. Participants even discussed professors or advisors who

consistently suggested they "re-think", or reconsider, their major. Additionally, women spoke about advisors who supported them, their scholarship cohorts, other women in their majors, and what has overall provided continued motivation to persist and not contribute toward attrition. These negative and positive experiences are necessary to fully elucidate the experiences of women and to develop an understanding of the engineering educational environments. A number of themes came to the forefront in the analysis of this work. It was decided that likewise themes would be paired up to create subsections to the findings.

The first main finding was discrimination and inequality, the experiences of women that led them to at times rethink their programs, reach attrition, or attempt to persevere. Second, the topic of mentorship and support rose as students talked about everywhere they branched out towards to receive support, and how mentorship was one of the most traditional and well mentioned forms of support. Lastly, the themes of achievement motivation and leadership, where women strived and why they aimed to.

Discrimination and Inequality

"*I think it was just yesterday, someone made the comment, 'Don't be a student woman in engineering," because [a woman] was having an issue trying to solve a problem. I guess they think [women] can't solve their own problems.*"

-Camille, Black Woman, Computer Engineering '23

Women in the engineering education environment have been known to experience a variety of problems relating to sexism and gender discrimination within their majors and in the field of STEM. To start, it is impossible to define what experiences contain ingrained sexism, are discriminatory, or may be simply problems bereft of the former two. As the primary investigator I don't have the context to be able to decide what an event means, but the women whose lived experiences these belong to, overtly explain the way they felt and what these events mean to them, and that holds importance. Women explained multiple events that felt discriminatory to them between their peers, professors, advisors and colleagues.

Women in both computer and mechanical engineering, mentioned that in both unofficial and official engineering spaces, such as study groups, classrooms, and labs, are described as male dominated. Participants argued that favoritism from instructors worked to push men into group positions with each other. This unification of men encouraged the women to feel "intimidated, unwelcome and unsupported" in these spaces. Other women mentioned that they felt they were also separated from other peer females in the classroom, and typically placed into groups with men for diversity purposes. Another computer engineering student also discussed that as they progressed in their program, the number of students, and peer women, were lessening, guaranteeing the majority of their remaining classes, including most 400 level lectures, will be male dominant.

In an interview with an alumna in mechanical engineering, Courtney, recalled one of many instances of sexism. She discussed how there were only a total of seven students in her

course. Due to the small population, this group would study together and eventually become a unit that did work together. Only two of the students were women, including Courtney. She was discussing equations with her women peers when her male colleagues started talking about a different group of women in the cohort. One woman, that Courtney knew of but was not close with, was brought up by a male colleague. “She was freaking super, super smart…and one of the guys starts talking about her and saying she’s not, and that the only reason she got a 4.0 was because she would go to the professor’s office and give him a blowjob.”.

Infuriated with the conversation and gossip, Courtney explained how the other four male colleagues contributed by agreeing with their male peer, mentioning how all the women were probably using sexual favors to get their grades. “I guess it’s naive, but I had no idea anyone in our class felt that way or had negative feelings about other classmates,” Courtney reflects, now a decade past her conferment. “Almost every single one of my memories about college…everytime I thought these guys were being nice and friendly, they’re actually being backstabbers.”.

Discriminatory practices are not only limited to peer-to-peer, but can happen within different power dynamics, such as professor-to-student, and advisor-to-student. Professor and advisory positions rely on leadership and mentorship, and the opinions of people in these positions can have a long standing impact on students' lives. Anna, Computer Engineering ‘23, mentioned that “when a student looks up to you, you're in a position of immense influence and power, especially students who look for guidance to make big decisions in their life, they’re going to take [what you say] very to heart.” Similarly, the actions of someone in these positions can be felt by students. Becca, Mechanical Engineering ‘24, when asked if she felt respected, hesitated for a moment and eventually explained how one particular male professor had been dismissive of her questions, answers, and emails which made her feel disrespected. “I couldn’t tell if that’s just how he was with students or if that is how he was with women.” Additionally, another student in chemical engineering believed that certain women professors liked to stick together, creating an effect where male professors might be excluded from instead of united in the efforts to help all students confer with their degrees. It’s important to recognize that although the majority opinions are covered in this paper, there are still certain women students who do not agree with the majority.

It was additionally noted that discriminatory practices are embedded in the curricula. Jasmine, a Black woman in Mechanical Engineering ‘24, spoke about her pain and anger upon finding out one of the basic engineering courses asks students to “make up a fake African country,” to solve an engineering problem, rather than use one of the 54 pre-existing ones that have their own myriad of real-world issues. She mentioned how she feels that there “are a lot of minorities not realizing the kind of brainwashing going on.”. She questioned herself and I, asking “how do we expose them [other minorities] to that?”. This question of exposure goes far beyond the works of this project, but it reminds people that not everyone identifies with their culturally ascribed factors or is passionate about it in this way.

No other engineering student mentioned the existence of this class assignment, so it’s unclear where it originated. When Jasmine mentioned it, she wasn’t sure if it was true, but for her it was a big deal. Jasmine had attended a community college that did community based

research, and to her it was astounding to think a university wouldn't work to analyze "real-world", or pertinent, non-abstract issues.

Mentorship and Support

"*The professor who told [me and the other women] that we should be more confident in our work, he's my faculty advisor. I hear from other students that he'll talk about how highly he thinks of me, he is very supportive.*"

-Camille, Computer Engineering '23

Support in the form of scholarship, athletics, and mentorship (both faculty and peer) were mentioned throughout the participant interviews. The effect that good support can have with student's retention is known through previous research. As expected, support and associated topics were spoken about multiple times in each interview. Support went beyond just standard mentor models, but expanded into non-traditional spaces. Examples of such spaces include a financial office that fought for an estranged student to get housing, and the reassurance of an alumna who had experienced the same situation. These preliminary findings demonstrate a small example of what is considered support and mentorship by our students and alumnae, where it was found, and by whom.

Support through a scholarship program is one of the more common stated forms amongst women in the field of engineering at UMBC. There are multiple scholarship opportunities available for students, either as freshman or transfer students at UMBC. Only the two main scholarships that were covered in the research interviews are explained here. The first was a women in technology scholarship, open to all gender classifications, but mainly for female identified STEM majors in COEIT. For the purpose of this study, it's called the Women's Scholars Program (WSP). The second scholarship, which was founded for minority/marginalized representation in STEM, will just be known as the STEM Scholars Program (SPS). Both of these programs are commitments that provide extra mentors, additional advisory meetings, and general support through finances, networking, and additional opportunities.

When asked about the support students have, many of them mentioned WSP, which works to retain women in STEM fields involving technology or cybersecurity work. "Having that community and support was very important to me. It's kind of what kept me here, why I won't go to another university and do something else, because I know no other university really has what we have here," Camille stated as a matter of fact when asked about WSP. Another alumna mentioned how her scholarship was what had felt like her only support system and the only way she could afford to attend the university, "For the first two years that I was there, 80% of my support came from SPS.".

Mentorship also came from fundamental places, such as from professors and people in advisory positions who have influence over students' choices, and sometimes even tenured alumna who either come back and assist or offer internships to students. Anna, a current computer engineering student, lives an experience that reflects the university's ability to support students from all directions. Taking a gap year after high school to better her life before becoming estranged from her parents, Anna relied heavily on the opportunities of the university

itself to get to the state safely and have housing. In the background of these incredible life challenges for a young student, she mentioned the people who had helped her throughout her journey thus far, particularly her department advisor. “He didn’t feel bad about the fact I was in this position. He was matter of fact about things and would ask if I could realistically complete classes. Definitely very supportive.” An additional student, Mallory, chemical engineering, mentioned how her education felt like it got better after she found support from a professor who runs a lab on campus, “The lab is what made me happy, and it made me realize that the stuff I learned in class is actually useful and not just random bullshit.”. This lab also opened Mallory’s eyes to graduate school and will be continuing to fund her education as she confers soon.

“*Before last summer, I would say I didn’t have a strong support system, then I joined a [campus] lab. After that I found I had more of a connection and a role model, there was a support group in the lab rather than what was provided from the department itself.*”

-Mallory, Chemical Engineering ‘23

The third and final important form of support and mentorship is peer-to-peer, or colleague-to-colleague. This is primarily a mentorship that happens between students and possible young alumni. Smaller majors, another student pointed out, have unity between cohorts more commonly: “Even if I’m not their best friend, I think everyone is united against the difficulties of chemical engineering,” Becky mentioned when asked about her peer support. These small cohorts make it difficult to separate men from women in group work, fostering a stronger sense of unity among the women in the cohort. “I do think the people in my cohort made it pretty welcoming,” Anna mentioned. Anna proceeded to say how she just had to “put herself out there” and try to connect. Now, Anna mentioned how she is tight knit with her friends and shares a healthy “give and take” with her peers.

Achievement Motivation and Leadership

“*It’s like saying to students: If you don't succeed the first time, give up and reconsider something you may not be interested in. Engineering is a skill, and some people are naturally talented at it, but you can build up those skills and get to the place where they are useful.*”

-Anna, Computer Engineering, ‘23

Women’s motivation and leadership is influenced by their opportunities, professors, peers, as well as sociocultural traits. To assist in the understanding of these influences, women were questioned about their hopes and perspectives about being or becoming leaders in their specific engineering fields, and often topics of their achievements, goals, and motivations flourished with these questions. Some students spoke about their current positions, while alumna explained what they currently do and how they wish to become a leader or see themselves as one. This was a core part of the interview that allowed women to develop more internal thoughts about themselves and their place in their career or program.

Becca, who serves in a leadership role for the American Society of Mechanical Engineering (ASME) student group, mentioned how she felt her natural leadership tendencies would serve her well in her future endeavors. She is hopeful that when she enters the workforce she’ll gain skills and end up in her own leadership position. “I'm hopeful that is where I will go

with my career because that is where I want to go.”. Hoping to gain the confidence necessary to reach her goals, she continues to look for leadership positions on and off campus. Other students, like Anna, have high intrinsic motivation and perseverance which has led to her own success running the university hackathon, HackUMBC. Her leadership comes as a result of her experiences and achievements from a life more filled with adversity than most. Similarly, her peer Camille mentioned how she knew she was going to stick with the major, no matter what. “To see that I’m failing at something, it upsets me, but I’ve never wanted to leave the major, I always knew I was going to go into computer or electrical engineering. That wouldn’t change no matter what.” This idea of persevering past failure and past the opinions of others (faculty, advisors, peers) came up often with people who admitted they were or have struggled in their courses.

In regards to professors and achievement motivation one student claimed that professors could be doing more to encourage students. “If we don’t encourage people to be [in engineering education] spaces, we are not going to have the people that we need in industry if we don’t encourage people to keep trying when they fail.” Another student mentioned that professors should respect students with diverse backgrounds more and that professors don't know what the future is. “You never know who will be the next Bill Gates, you know what I mean? I just feel like you never really know what the future holds and what you do today can have a big impact on that.”. If there is something I as the researcher have retained from the students through these interviews, it is that professors, when promoting motivation to learn and achieve, should remember what their experiences were as a student.

LIMITS AND FUTURE DIRECTIONS

The limits of this research exist and follow traditional issues commonly associated with qualitative research. The first limitation was the response from possible participants. 33 alumna and 31 undergraduate students submitted their interest in participating, from a pool of roughly 600-700 women. Although this data has not reached saturation of all topics, it is becoming saturated with each additional interview. The study is representative of many personal experiences of undergraduate women in engineering, but not the entirety. It isn’t possible for research to be inclusive of a population of this size.

A future research direction to be considered would be a longitudinal approach using an adaption of the Beginning Postsecondary Students (BPS) survey [21]. This survey tracks a cohort of students in their freshman year and subsequently every following three years, could be adapted to get complex patterns of undergraduate attrition and retention through looking at a large-to-mid size university’s entire cohort of engineering students, and interviewing them every two years, over a designated period of time to see how they adapt post-graduation, following their departure from the university. One of the main concerns about retaining and producing talent in the fields of Science and Engineering in the United States is that the undergraduate students who start in these fields of study do not complete their degrees in those same fields [2]. If the BPS survey is adjusted there could be a more complex understanding of major switching behavior and adjustment into life post-postsecondary institution.

In the collection, analysis, and dissemination of this project's data to various stakeholder audiences clear future research directions and academic policy implications exist. Future research directions could include instead of using women's experiences, focusing directly on intersecting experiences, to thicken the understanding and available description of marginalized experiences [20].

CONCLUSION

This project addresses the national goal of increasing the percentage of women participating in the various engineering fields where they are currently underrepresented (e.g., chemical, computer, and mechanical engineering). The project is expected to impact and generate information to improve practice in multiple fields of study including social science research, engineering education research, and higher education administration. With the continued development of this work qualitatively the researchers hope to increase the retention of students in the field of engineering.

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