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Experiences of Female Undergraduate Engineering Students in Academia and Industry: A Literature Review

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ABSTRACT

Higher educational settings have a slow rise of women in engineering programs. This literature review synthesizes existing research and has intentions to gain further understanding of female undergraduate engineering students—such as perceptions and experiences—on their respective university campus and internship programs through answering the below the main research: What is the nature of experience for female undergraduate engineering students on university campus and internship programs? This literature review provides important insights of needing support programs at early stages for students in their undergraduate education. Early interventions such as informal mentor relationships provide female students with stronger engineering identities for female engineering students. Ten research articles are examined in this literature review. The selection criteria emphasize on primary, peer reviewed articles that had to be in English with recent publications (earliest publication date of 2007) in the engineering or STEM field, the article revolved in higher education settings with students, faculty or staff as participants, article research objectives involve with gendered issues or mentorship programs and lastly, the articles involve with internship or academic support. Although the literature across were all in English, this literature review contains research from other countries—though mainly are from United States—Australia, England, Brazil, Spain and Kazakhstan. The variety of countries included provided consistencies that contextual support and supportive programs are crucial for fostering greater self-efficacy, persistency and resiliency for female undergraduate engineering students.

INTRODUCTION

Higher educational institutions have a persisting slow rise of women enrolling to engineering programs. The United States' National Science Foundation (2020) reported that 18.25% of females were enrolled to an undergraduate engineering program in 2010 and there was a slight increase to 22.67% in 2018. In addition, the National Science Foundation (2020) also reported that, in the year 2010, 60.47% of the undergraduate students—American citizens or permanent residents—in the engineering program are comprised of predominately White students; second, Hispanic or Latino at 10.86%; third, Black or African American students at 5.64%; fourth, other or unknown race or ethnicity at 5.63% and finally, American Indian or Alaska Native students at 0.50%. It is important to note that the data for Asians and Native Hawaiian or Other Pacific Islanders were not available in 2010. Subsequent reports after 2010 provided data; however, the percentage of Asians, Native Hawaiian or Other Pacific Islanders remained relatively the same. The last updated report from National Science Foundation (2020) was in 2018: White at 54.17%; Hispanic or Latino at 14.37%; Asians at 10.58%; Black or African Americans at 5.14%; Other or unknown race or ethnicity at 2.48%; American Indian or Alaska Native at 0.32%; Native Hawaiian or Other Pacific Islander at 0.15%. The report by National Science Foundation illustrates the cultural hegemony in educational institutions—particularly engineering programs—regarding the prevalence of a homogenous demographic: White men.

In addition to issues of diversity and inclusion in an educational and institutional standpoint, the problem also extends to workforce projections in having a shortage of STEM workers in the United States (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2019). With the compounding issues of supply and demand in the engineering labour market, it is now more important than ever to prevent this workforce projection by encouraging, fostering and instilling a diverse population of engineers that have been long underrepresented: women and people of color.

When it comes to self-efficacy—a belief that one can succeed through their abilities (Bandura, 1986)—research has shown that women have higher tendencies to exude lower self-efficacy levels when compared to their male peers in their undergraduate engineering program (Riney & Froeschle, 2012; Smith, & Gayles, 2017; Joiner *et al.*, 2010; Raelin *et al.*, 2014; Garcia-Holgado *et al.*, 2020; Almukhambetova & Kuzhabekova, 2020; Ong *et al.*, 2018). As such, having high self-efficacy levels—regardless of gender—help with resiliency and persistence for remaining in undergraduate engineering studies and as a practicing engineer upon graduation (Riney & Froeschie, 2012; Smith, & Gayles, 2017; Raelin *et al.*, 2014; Garcia-Holgado *et al.*, 2020; Almukhambetova & Kuzhabekova, 2020). However, the persistence is short-lived because women tend to leave the engineering profession at higher and faster rates than men (Riney and Froeschie, 2012;

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Almukhambetova & Kuzhabekova, 2020; Male *et al.*, 2018; Garcia-Holgado *et al.*, 2020).

Adding onto cultural hegemony, gender schemas—a process of how people categorize knowledge which becomes a heuristic for conforming to their own gender that ultimately adheres to societal expectations (Bem, 1981)—the engineering environment asserts greater gender hegemony in this profession through the exclusion of women from fully participating equitably in academic and work settings (Male *et al*, 2018; Riney & Froeschie, 2012; García-Holgado *et al.*; 2020; Almukhambetova & Kuzhabekova, 2019; Ong *et al.*, 2018). As such, this illustrates the ways that engineering fields—academic and workplaces—concedes to be places that is "historically designed for male in engineering" (Riney & Froeschie, 2012).

Objective

There has been a lot of research on familial support (Raelin *et al.*, 2014; García-Holgado *et al.*, 2020; Almukhambetova & Kuzhabekova, 2019; Ong *et al.*, 2018; Smith and Gayles; 2017;), socialization, and gender dynamics (Riney & Froeschie, 2012; Ong *et al.*, 2018; Joiner *et al.*, 2010; Raelin *et al.*, 2014; Kim *et al.*, 2011; García-Holgado *et al.*, 2020; Almukhambetova & Kuzhabekova, 2019) for undergraduate engineering students in higher education. In addition, there is previous research, though limited compared to support and socialization, about undergraduate engineering student experiences on their internship program. However, there are gaps in research on intersections of support in academics and internship programs. Understanding the relationship between the presence and absence of support systems in educational engineering programs—academic and internships—bridges the gap for students transitioning from class to internships and eventually the professional working field in engineering.

This literature review synthesizes existing research and has intentions to gain further understanding of female undergraduate engineering students—such as perceptions and experiences—on their respective university campus and internship programs through answering the below main research and sub-questions.

MATERIALS AND METHODS

Main Research Question

What is the nature of experience for female undergraduate engineering students on university campus and internship programs?

Sub-questions. What are female engineering students' perceptions of their experiences on university campus? What are female engineering students' perceptions of their experiences in internship programs? What is the relationship between support programs that exist for assisting and/or supporting female students in their engineering programs and internships?

Literature Search Strategy

The University of Toronto's library website was used for this literature review to search for peer-review articles with the default LibrarySearch feature. Instead of using Boolean operators, organic keyword searches were used instead. Two organic keyword searches were conducted using "female undergraduate engineering internship" and "female undergraduate engineering student support".

Selection Criteria

This literature review emphasizes on primary, peer reviewed articles for the selection process (see Table 1). As such, primary, peer reviewed articles that were selected had to meet the following criteria: one, article needs to be written in English; two, publication of the article had to be recent with the earliest publication date of 2007; three, article has to be in the engineering or STEM field; four, the article consists of student participants that are in higher education or faculty or staff members involved in engineering; five, article has research objectives that involves with internships or academic support; six, the article research objectives involve with experiences that pertains to gendered issues or mentorship or support programs. When articles met with the criteria mentioned above, they were selected based on search result relevancy.

RESULTS AND DISCUSSION

Themes

Gatekeeping Gender in Academia and Workplace

Academia: Male Peers

For undergraduate engineering academic settings, gatekeeping is consistent across the literature which included male peers, teachers and professors. Due to the underrepresentation of female engineering students, they are often the only female member in groupwork settings. As such, being the only female member in the team leads the dominate members—males—to utilize power and gender schema to reinforce gender differences through exclusion. For example, Riney and Froeschie (2012) recalled a past experience of a female student by which her male peers stated that she was not needed, and her only task was to serve coffee for her male peers. Exclusionary practices by male students reinforced socialized norms in groupwork settings in two ways: one, male peers discounted their female counterparts when they actively participated in groupwork because their gender—as female—defaulted the assumption that females have limited understanding to engineering knowledge; two, male peers subjected or expected their female peers to play supportive and nurturing roles which included taking notes and other secretarial roles (Riney & Froeschie, 2012; Kim *et al.*,2011; Garcia-Holgado *et al.*, 2020; Almukhambetova & Kuzhabekova, 2020; Smith and Gayles, 2017).

Academia: Educators

Female engineering students also reported educators being gatekeepers as well. Garcia-Holgado *et al.* (2020) and Almukhambetova & Kuzhabekova (2019) recalled teachers showing gender bias throughout their high school experience—spending more time with male students in science and math classes and discouraging

female participants from choosing STEM in higher education because it is deemed inappropriate for women to be in the STEM field. Engineering educators—professors and instructors—fostered gender-exclusive environments through gender-biased statements of women not belonging to the engineering field (Ong, 2020; Riney & Froeschie, 2012); with that said, discrimination from educators fosters unintended consequences of systemic gender exclusion by which male classmates are empowered to partake active roles in gender gatekeeping.

Work in the Engineering Field

Literature across work experiences—experiential learning opportunities such as co-operative education and internships—discussed gatekeeping practices from male colleagues. Abstaining and denying the purchase of proper personal protective equipment (PPE) for female workers while purchasing new equipment for male workers fostered inequities and dangerous work environments because old shoes and PPE did not fit them properly (Male *et al.*, 2018). Additional discriminatory and sexual harassment behavior was common for female students that sought work experience in the engineering field. The former example, discrimination, led to a common practice by which male colleagues discounted the validity of the female intern's technical knowledge which led them to disregard or downplay their provided solutions or issues (Male *et al.*, 2018; Smith & Gayles, 2017). The latter example reported a female student being denied the use of the women's washroom at the building she worked in because her male colleagues locked the women's washroom for a period of time. This situation forced her to either use the male's washroom or go to another building to have access to a women's washroom (Smith & Gayles, 2017).

Masculinity Gatekeeping

Men also policed masculinity amongst themselves. In academic and work realms, men would make sexual remarks or references to maintain masculinity within the male dominated group and this also served to exclude females if they were present (Ong *et al.*, 2020; Male *et al.*, 2018; Riney & Froeschie, 2012; Smith & Gayles, 2017). Male classmates and colleagues would also use their female counterpart as part of their sexual remarks or dialogue—for example, asking their female classmate to be a Playboy Bunny for Halloween (Riney & Froeschie, 2012) to male colleagues taking turns every week asking their only female colleague on a date for the entire duration of her 12-week internship (Smith & Gayles, 2017). Accountability was entrenched within the male dominated engineering work field: male interns were reprimanded for doing work that was socially labelled as feminine while male interns were commended for partaking in socially labelled activities that are viewed as masculine (Riney & Froeschie, 2012; Male *et al.*, 2018).

Contextual Support

Across the literature, family, educators (high school teachers and post-secondary professors), representative role models, female representation, male figures, and school support programs served as sources of contextual support for female engineering students. Contextual support provided female undergraduate engineering students with greater resiliency and self-efficacy levels (Riney & Froeschle, 2012; Smith, & Gayles, 2017; Joiner *et al.*, 2010; Raelin *et al.*, 2014; Garcia-Holgado *et al.*, 2020; Almukhambetova & Kuzhabekova, 2020; Kim *et al.*, 2011; Ong *et al.*, 2020).

Family

Female undergraduate engineering student's family were their greatest form of contextual support. Parental and other familial members provide positive affirmations and high expectation that the female student can succeed in STEM (Almukhambetova & Kuzhabekova, 2020; Riney & Froeschle, 2012). In addition, when the student declares the pursuit to study engineering, familial members continue to foster a supportive environment so that the female student can persevere and persist in the engineering field: academically and professionally (Almukhambetova & Kuzhabekova, 2020; Joiner *et al.*, 2010; Riney & Froeschle, 2012; Smith, & Gayles, 2017; Garcia-Holgado *et al.*, 2020; Kim *et al.*, 2011; Ong *et al.*, 2020; Raelin *et al.*, 2014). In particular, the support and assistance from male family members are provided in two ways: one, familial male support instilled greater confidence and self-efficacy levels for female students (Riney & Froeschle, 2012; Almukhambetova & Kuzhabekova, 2020); two, male family members bridged the gaps of knowledge that female students were not socialized to learn—i.e. mechanical application of a car—when compared to their male peers (Riney & Froeschle, 2012).

Educators

Teachers and professors that supported female students to pursue engineering in university had higher self-efficacy levels. High school teachers also took a pivotal role for encouraging female students to pursue engineering. Positive learning experiences and teacher interaction in math and science classes led female and male students to pursue STEM as their major in higher education (Garcia-Holgado *et al.*, 2020; Almukhambetova & Kuzhabekova, 2020).

Faculty members in higher education were also sources of contextual support for female undergraduate students. In particular, undergraduate students in lower divisions—freshman and sophomore years—sought informal mentorships with faculty members and graduate students fostered stronger STEM identities, resilience, persistence and self-efficacy (Raelin *et al.*, 2014; Smith and Gayles, 2017; Kim *et al.*, 2011; Hernandez *et al.*, 2017) compared to students that matched with one mentor in formal mentorship programs (Hernandez *et al.*, 2017). Furthermore, informal mentorships that female undergraduates sought fostered greater motivation and interest for STEM, and 50% of the participants had

plans to apply for graduate school (Kim *et al*, 2011). The presence and availability of role models—guest speakers, faculty members, graduate students and industry colleagues—for female undergraduate engineering students in academia and internship workplaces fostered the socialization of female students into the engineering profession. Male educators that fostered a supportive environment in engineering also served as reasons for female students to persist in the engineering field (Riney & Froeschle, 2012;).

Support Programs

In academia, female students took the most advantage of mentorship programs—when available—regardless if they are formal or informal. Support programs served as a space where they get support, advice, exposure and pathways for school (engineering specialization, graduate school), and career options (Kim *et al*, 2011; Hernandez *et al*., 2017; Raelin *et al*., 2014). Hernandez *et al*., (2017) reported that informal mentorships was an outlet to building a bigger engineering network because faculty members referred female students to other faculty members, industry contacts, events and opportunities (Hernandez *et al*., 2017; Kim *et al*., 2011). In addition, engineering programs that offered support to improve application knowledge was also taken advantage by female students. Findings from Male *et al*. (2018) showed that school interventions that offered video games to bridge the gaps of understanding mechanical engineering applications helped improve female students' application knowledge and self-efficacy. As a result, equity levels were achieved by levelling the gaps of mechanical engineering applications between the two genders.

In the working realm, female undergraduate students on their internships utilized the opportunity to gauge if this is a suitable workplace or profession to be in upon graduation (Male *et al*., al., 2018; Kim *et al*., 2011). In addition, female students would also look into other factors during their internships which included visible female representation at the workplace, available support, work-life balance and overall work environment and culture (Smith and Gayles, 2017; Kim *et al*., 2011).

DISCUSSION

Socialization process through gender schema takes place in meso and macro levels. Family and school were sources of meso level socialization process of gender which fostered female students to persist with self-efficacy in the engineering field. Meeting standards to hegemonic culture is a macro level socialization process. The meso and macro level builds upon the fostering of persistent gender schemas which can extend male privilege and dominance in the engineering field if interventions are not made to ease the marginalisation of women in this profession.

Overall, female engineering students experience marginalization at their university's engineering program and internship placements. Hegemonic through time, history and tradition, educational systems is "conservative from top to bottom and sideways" (Fullan, 2020, p. 661). The conservative nature of higher education extends to engineering academic programs by which the profession is "designed historically by men for male engineers" (Riney & Froeschle, 2012, p. 97). Through this, the meso level of gendered socialization within families and in academia reinforces the unintended consequences of an uneven representation of male and female undergraduate students in engineering and in the working profession. Moreover, male dominance in engineering furthers gatekeeping and maintenance of a masculine culture. As such, female undergraduate students, across the literature, perceive their engineering experiences at school and intern workplaces as challenging due to the inequities in regard to accessing proper resources and equipment because they are discriminated for their gender—thereby confining female students to partake in societal gendered roles of being supportive in groupwork settings (Riney & Froeschle, 2012). Marginalization can be viewed as proliferated across literature that pertained to female engineering students on internships. From being in the office to do secretarial work, denied access to women's washroom and personal protective equipment to having supervisors or colleagues outwardly believing that engineering is not for women (Kim *et al*. 2011, Male *et al*., 2018; Smith & Gayles, 2017), female engineering students become susceptible and vulnerable to self-manifesting to society's gendered culture.

The marginalization process impacts female student's self-efficacy, resiliency and persistency to continue on engineering as a profession. However, contextual support serves to provide female students to persevere in engineering. With that said, contextual support at meso levels—familial and academic support—is crucial to foster female students with greater self-efficacy and resiliency in engineering. Family members and educators instilling perseverance, high expectations, and guidance (mentors and role models) are not enough to help female students adapt and transition to university and internship workspaces. Interactive support programs—such as video games—that bridge gaps of engineering applications (Male *et al*, 2017; Riney & Froeschle, 2012) is much needed so that female students can have the equity they need to succeed. In addition, collaborative mentorship programs to help the transition from academics to internships for female students is much needed. In particular, providing strategic interventions that support female engineering students to build informal mentorships in their early years of their study helps to foster a strong engineering identity and self-efficacy levels to persist in studying and pursuing engineering (Hernandez *et al*., 2017). More importantly, engineering programs need to be proactive in working with employers for building a collaborative support program for female students at work. Through collaborations between engineering internship programs and employers via supportive programs, effective strategies through policies, training and support systems

can counter exclusionary and microaggression practices. That way, female students that are on their internship can build heuristics which empowers them to persist and be prepared in a field that is predominately masculine while being supported in an equitable environment at work.

Table 1: Literature reviewed about the experiences of female undergraduate students in academia and industry

Author and Publication Year	Country	Research Aims, Research Method, Method of Analysis	Major Findings
Male *et al.* (2018)	Australia	Explore gendered workplace culture of students in engineering workplaces; qualitative research; thematic analysis	Students experience gendered culture at workplace: collaboration with educators and employers is needed to change and prepare students about workplace culture.
Riney and Froeschie (2012)	U.S.A.	Explore the socialization process for male and female undergraduate engineering students; qualitative research; thematic analysis	Stress is the gender commonality. Differences include females partaking in supportive roles in groupwork. Gatekeeping from male peers and professors at research universities (Division 1) in contrast to teaching universities (Division 2)
Smith and Gayles (2017)	U.S.A.	Explore the career decisions of female engineering undergraduate students that were graduating; case study using qualitative research; thematic analysis	Undergraduate experiences affected how they decided to choose particular jobs in the engineering field which led to themselves having greater self-awareness and finding a job that aligns with their values (welcoming environment with women working at the company)
Joiner *et al.* (2010)	England	Explore the gender differences and benefits of playing video games for students studying mechanical engineering (undergraduates); quantitative research; descriptive data analysis	No gender differences for video games; Video game benefited students learning mechanical engineering and both genders participated equally; female students found the video game led to more motivation to study engineering
Hernandez *et al.* (2017)	U.S.A.	Explores how mentorships can impact female undergraduate students to have persistence in STEM; quantitative research; regression analysis	Early interventions for mentoring lead to having multiple informal mentorships; multiple mentors increase self-identity, greater interest and persistence for studying STEM compared to having only one mentor; Schools need to start mentorship early; faculty members as mentors help students with persistence to stay in STEM
Raelin *et al.* (2014)	U.S.A.	Explore the effectiveness of engineering co-op programs for retaining undergraduate students to remain in this discipline; quantitative research; inferential analysis	Women take more advantage of support services; services should be available at early stage rather than latter half of undergraduate studies; schools intervening with support services for women helps with retention; academic and work self-efficacy is associated with high GPA, contextual support and co-op experiences supports retention for both genders
Kim *et al.* (2011)	U.S.A.	Explore the effectiveness of REU programs for undergraduate students in computer science engineering (CSE) and whether REU promotes persistence to remain in engineering; mixed methods; framework analysis	Undergraduate students in CSE benefit from research experiences; women benefit more if research involved more collaboration that included more practical and interdisciplinary involvement; discussion of gender equity issues naturally instead of workshops has a positive response for female undergraduate students; absence of work experience in engineering may be an issue to negative responses for gender equity workshops

García-Holgado *et al.* (2020)	Brazil & Spain	Explores the role of support can influence students to pursue and persist in engineering studies; quantitative research; descriptive analysis	Secondary school's role of providing support plays a role for students on deciding to study engineering for women in both countries; regardless of gender, the level of support provided by tertiary schools plays a role for dropping out of engineering
Almukhambetova & Kuzhabekova (2019)	Kazakhstan	Explore female undergraduates' decision-making process for majoring STEM; qualitative research; framework analysis	Family and secondary schools play strong roles for choosing STEM fields—opinions from family, particularly male family figures, and staff play a strong process for choosing STEM; Location also plays a factor for enabling or disabling women from choosing STEM as their major
Ong *et al.* (2020)	U.S.A.	Explore approaches by women of color (WOC) enrolled in engineering programs and provide intervention recommendations to engineering schools to support WOC; systematic literature review	Intersectionality affects inclusion and creates more barriers and oppression in engineering that is systematically a White and male dominated academic discipline; WOC affected by instituion inequities experience social pain: support provides WOC to persist in engineering

Strengths

The strength of this literature review raises the awareness and importance of needing support programs at early stages for students in their undergraduate education. Early interventions in freshman and sophomore years foster informal mentor relationships and stronger engineering identities for female engineering students. Furthermore, early inventions provide greater benefits of building a stronger female community that supports each other while building networks and relationships throughout their academic and professional journey. Another strength of this literature review is the effectiveness of having supportive family members, representative role models, mentors and supportive educators for building their engineering identity, self-efficacy and persistence in the engineering profession.

Although the literature across were all in English, mainly from United States, this literature review contains research from other countries—Australia, England, Brazil, Spain and Kazakhstan. This provides consistencies by which supportive programs and contextual support are crucial for fostering greater self-efficacy, persistency and resiliency for female undergraduate engineering students.

Limitation of the Study

The limitation of this literature review is that this study looks into one marginalized group: woman. As such, emphasizing the study about woman overlooks the marginalization of other vulnerable population through the lens of intersectionality. For example, when gender intersects with race, identity and disabilities, students can experience greater barriers, discrimination and exclusion at work and school. Essentially, the study does not explore issues of many marginalized groups. For example, other marginalized groups in engineering that are also vulnerable in this male dominating field is the 2SLGBTQI+ community. Garcia-Holgado *et al.* (2020) reported two nonbinary genders in the study that had to endure more difficult experiences when compared to women; however, the low distribution of participants in the study is not representative for generalizability in regard to barriers and discrimination for 2SLGBTQI+ undergraduate engineering students. Another limitation is the absence of persons with disabilities. Literature that was examined in this review did not have any students with disabilities as their participants. More studies need to look into engineering fields that can facilitate students with disabilities and include them in research so that there are more diversity and inclusion in this homogenic field. With that said, further research is needed for other vulnerable groups such as the 2SLGBTQI+ and persons with disabilities community.

I identify as a woman, a person of color, an ally towards equity, diversity and inclusion, and a staff that works in an engineering co-operative program at a public university. I address that the nature of my position may provide bias because I work with engineering students—male and female—and have built closer connections with male students compared to female students. In addition, my experiences of following up with student feedback—gender-related issues such as exclusion and inequities—from female students has met with limited to no response. This peaked my questioning of educational services provided to female students as inequitable and through their lens, the educational services may be perceived as unhelpful. This literature review hopes to serve as a starting point to understand the gaps at my work so that program changes such as better resources, and services can be improved.

CONCLUSIONS

Despite a strong call for greater female representation in STEM, hegemonic societal expectations persist which alludes conflicting messages for female students

navigating their studies and internships. Even though the engineering field is hegemonically constructed as a masculine profession, it is now more important than ever to create and maintain supportive programs and platforms for female engineering students so that diverse and inclusive groups can persist. The benefits of collaboration between academia and industry for creating supportive and inclusive programs can help to attract and maintain female engineers to stay in the field. Educational change in engineering programs is needed to foster inclusion and diversity.

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