Women enrolled in engineering programs: Their interests and goals

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Although women earn about half of science and engineering bachelor's degrees, and 44% of master's degrees, women are underrepresented in certain areas of science and engineering [1]. According to the National Science Foundation, women received the highest amount of science degrees in psychology and biosciences, and the lowest in computer sciences and engineering [1]. Why are women entering the fields of psychology and biology and not engineering or computer sciences? Many research studies have aimed to answer this question in various ways, including examining women's math and science identities [2], confidence and self-efficacy [3, 4], perceptions and experiences [5], and larger, structural issues [6]. This study aims to identify women's main motivating factor to pursue an engineering undergraduate degree. We are interested to find out how women are influenced to choose this career path, and what influences them.

Introduction

This study took place at the University of Georgia, United States, and focused on undergraduate women enrolled in engineering majors. The college of engineering has recently received national recognition for their diversity programs [7] and as of fall 2018 had over 2000 undergraduate students enrolled [8]. Although overall the university enrolls more undergraduate women [9], this is not true for the college of engineering. As reported in 2016 only 24% of undergraduates and graduates seeking engineering degrees at this university were women [10].

A search of the literature was conducted using the ERIC database, and 89 peer reviewed, academic journal articles published in the last 15 years were found to be relevant to the current study. To be included as a relevant study, the focus had to be on factors influencing women's decisions to major in engineering and/or gender differences in influences to choose an engineering or STEM major. Twenty-eight studies clearly met these criteria and are briefly reviewed below.

Seven studies focused on high school students' attitudes towards STEM majors and careers [11-17], one study focused on women in community college [18], seven used longitudinal data [19-25] and the rest of the studies focused on undergraduate students [26-38]. Studies took place in 7 countries (i.e., the US, UK, South Korea, Chile, Turkey, Israel and the UAE). Major themes throughout the studies include relating students' self-efficacy and interest measures of STEM disciplines, socio-economic status (SES), and STEM discipline expectations to STEM major choice and persistence. Additionally, gender differences in interest and persistence across STEM fields was examined [19, 22, 27,30, 36], as well as interests in engineering specifically [12-15, 28-29, 31-33, 38].

There were cross-cultural differences in the studies' findings. In the study from UAE [26], women with higher SES were less likely to choose STEM majors and careers (Fig. 1), unlike in the US and UK where studies found higher SES to significantly impact the likelihood of persisting in and choosing a STEM major, respectively [22, 24]. In Caspi et. al.'s study [16] in Israel, they found no gender difference in ninth grade students' choice of a STEM major whereas

gender differences were found early on (i.e., prior to intervention) in STEM attitudes in US students [13].

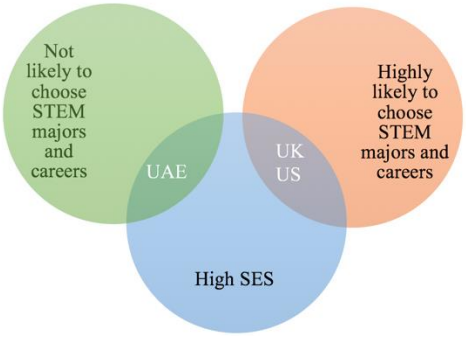

Fig. 1 Likelihood of persisting in and choosing a STEM major

Importantly, these studies support the disaggregation of STEM fields when examining students' major and career choice across gender. Looking at STEM as a whole may misrepresent the number of and success of women in science, as well as miss the opportunity to identify the specific disciplines with low-female enrollment, such as physics and computer science. Several studies found that women were interested in/chose science and health-science related majors at equal or higher levels than men [13, 17, 21, 31, 32 ,34, 37]. Studies with high school students in the US [1] and Turkey [5] found female students were more interested in science (e.g., biology, environmental engineering) and less interested in physics, math, and computer science. In a study focused on low-female enrollment engineering fields, [28] participants cited social stereotypes and the immediate environment, as well as lack of interest, as reasons for the low enrollment of women in these fields. It is important to understand both women's interest and lack of interest in specific STEM disciplines if the goal is to increase women's participation across all disciplines.

Major influences on the decision to choose a major/career included interest/preference [16, 31-32, 38], utility [16], career expectations [31-32], family influences [15], innovation and making a difference (social) [33, 38]. In general, these influences on decision-making were true for both men and women across STEM fields. Additionally, self-efficacy in STEM disciplines was examined as it related to choice of major/career in multiple studies [17, 25, 29-32]. Gremillion et. al [17] found difference in self efficacy in engineering and technology between men and women, with men having higher self-efficacy, however no difference was found in math and science. Lent et. al [31] reported no significant difference on social cognitive variables between genders, aligned with their earlier studies where male and female engineering students reported similar academic self-efficacy. Findings from a South Korean study [32] support this, having found no difference in self-efficacy between genders. However, other studies contradict these findings, focusing on mathematics self-efficacy and attitudes as correlated to choice of STEM major, and finding that men rate their efficacy in mathematics higher than women [17]. It is also important to look at SES as a factor as higher SES students tend to have higher grades which may lead to higher reports of self-efficacy across disciplines.

By identifying the influences and interests of the undergraduate women enrolled in engineering majors, the ultimate goal of this study was to identify possible avenues to invest our

effort towards enhancing the recruitment and retention of female engineering students. The study was guided by the following research questions.

1. What do women identify as influences for enrolling in an engineering major?
2. What role does their educational and family backgrounds play in their success, as measured by GPA?

To answer the research questions, female undergraduates at the University of Georgia (UGA) in the southeastern United States were invited to complete a 20-question survey that asked them to identify their reasons for enrolling as an engineering major, as well as their personal and family educational backgrounds. A majority of survey participants chose engineering because they were interested in it or because they thought it would lead to a successful career. About half of the students had at least one family member working as an engineer. In a study by Mativo and George [47], it was found that engineering women have a great influence on the career choice of their daughters. In particular, among women engineering professionals who had daughters who were attending college, 54% were pursuing a degree in engineering. A remarkable number, given the low enrolment of women in engineering.

The current study indicates that interest is a major driving force for women to choose engineering. Therefore, this study motivates the need to further investigate the impact of a family member working as an engineer on women's interest in pursuing a career in engineering.

Methods

Research design

A survey with four sections was designed using the online program Survey Monkey in late 2018. After consent information, the first question asked, "Are you a female enrolled at UGA as engineering major?" with the options "yes" or "no." If they chose yes, they continued to the rest of the survey. If not, the survey closed, and they were taken to a page thanking them for their time. The survey included four content sections: demographics, engineering interests/influences, personal educational background, and parental educational background. A total of 20 questions, including 13 multiple choice and 7 open-ended response questions, were on the survey. The survey took between 3 and 10 minutes to complete.

Female engineering students were contacted via their school emails and asked to complete the survey in late March 2018 (n=510). A reminder was sent out two weeks after the initial email and the survey remained open for responses for approximately 1 month. All except 10 responses were received in the first two weeks of the initial email. We received a total of 186 responses, however 12 of these responses were from graduate students. These responses were removed, creating a total data set of 174 responses from undergraduates. The response rate was 36.5%. This data set was analyzed as described in the next section.

Data analysis

Each survey question was analyzed for descriptive statistics using Microsoft Excel. All open-ended responses were coded by hand in excel based on content. Common codes were grouped together, and instances counted and reported. To answer the first research question, What do women identify as influences for enrolling in an engineering major? we analyzed two multiple-choice survey questions about participant's influences via descriptive statistics and two open-ended response questions via coding and grouping. For the second research question, What role does their educational and family backgrounds play in their success, as measured by GPA, the statistical software program IBM SPSS was also used to implement chi-square tests for independence. Chi-square tests for independence were used to determine whether participant's educational backgrounds (e.g., involvement in a STEM-focused summer camp) and/or family backgrounds (e.g., family member in engineering) were significantly associated with their success, as measured by their current GPA.

In order to create balanced categorical groups from the GPA data, participant's numerical responses were grouped into three categories: Low, Middle, and High. The Low group included GPAs from 1.6-3.0 (n=35), the middle group from 3.1-3.5 (n=69), and the high group at 3.6-4.0 (n=70). Additionally, the responses for parental educational attainment were grouped into three categories: High school, College, and Graduate. The High school category included those who did not finish high school, unknown, and high school graduates. The College category included those who completed some college, and a 2-year or 4-year degree. Finally, the Graduate category included those who had completed graduate school. The number of responses in each category were counted separately for participant's mothers and fathers.

Results

Demographics and Educational Background

A majority of the participants identified as white (n=121). A smaller number of participants identified as Asian (n=27), African American (n=15), or Hispanic (n=11). Six participants also identified as biracial. Freshmen were the largest group of respondents (n=47), while the number of sophomores, junior, and senior responses were about equal (n=37, n=37, n=36, respectively). Also, 17 students were in their 5^{th} or 6^{th} year. Most participants had at least a B-grade point average (GPA), defined as a 3.0 or higher (n=139).

Most participants attended a public high school (n=142) or a public charter school (n=12). The high schools they attended were largely in the same state as the university they were enrolled in (n=138), although 20 attended high school in another state and 5 attended high school in a country other than the US. About 37% of respondents attended an art-focused summer camp at some point in their K-12 education (n=64) while about 23% attended a STEM-focused camp (n=40).

Engineering Interest

All respondents were currently engineering majors, with the largest response coming from the mechanical engineering program (n=38), followed by environmental engineering (n=31). All the bio-disciplines together accounted for around 35% of participants (n=60). The distribution of female engineering students across disciplines in this sample somewhat aligns with previous research that found women are more likely to choose environmental and bio-focused disciplines [39, 40]. Yoder [40] reported the national percentages of women awarded bachelor's degrees in disciplines of engineering for the years 2014-15. According to this, the percentage of respondents for mechanical engineering (approximately 22%) is higher than the national percentage of bachelor's degrees awarded to women in that discipline (13.2%), while the percentage of respondents for biomedical engineering (approximately 17%) was lower than the national percentage (40.9%). However, not all of the disciplines represented in current study were included in Yoder [40].

The engineering program examined in the current study is relatively new among comparable universities. Table 1 presents the number of participants enrolled in each engineering discipline at UGA.

Table 1: Participants' Engineering Discipline

Discipline	*n*
Agricultural	6
Biological	19
Biomedical	29
Biochemical	17
Civil	20
Computer Science	3
Computer Systems*	11
Electrical*	5
Environmental*	31
Mechanical	38
Total**	179

** Data was entered in by participant in "other" category*
*** Total includes 5 participants who choose 2 disciplines (biology and biomedical)*

When asked what their "most important" reason for enrolling in engineering was, the most common choice was, "Interested in the major/discipline" followed by "Thought it would help me get a good job/career after college" (Table 2). No participants selected "Was forced to choose it" as their reason, a good indication for the field. Very few were influenced to choose the major by a friend or high school teacher or guidance counselor. A small percentage chose family recommendation as the most important factor in their choice of major. Additionally, 10 participants chose "other" and wrote in their own reason. These reasons were coded based on content and then grouped. The two groups that emerged expressed a desire to impact society (n=4) and enjoyed the challenges of engineering (n=3).

Table 2. Most important reason for enrolling in engineering

	n
Thought it would help me get a good job/career after college	46
Interested in the major/ discipline	103
Friend recommended it to me	2
My high school teacher/ guidance counselor recommended it to me	1
A member of my family recommended it to me	11
Was forced to choose it	0
Other (please type your response)	10
Total	173

Engineering Influences: Family Background

Almost half of respondents had a family member in the engineering field (n=83). The most common family member in engineering was a father (n=38) followed by the "other" category (n=27). The other category requested respondents to write-in their responses, which included uncles, aunts, cousins, and grandfathers. It was far less common to have mothers, sisters, and brothers in engineering (n=6, n=4, and n=8, respectively). Although respondents did not choose family influence as the most important reason they enrolled in engineering, it is interesting to see nearly half of them had an engineer in their family. This may point to the role having a family member in engineering plays in choice of major, despite not being indicated as the "most important" by respondents.

Although it is uncertain what role having a family in engineering played on the participant's choice of major, we wanted to see whether this background influenced their success, as measured by GPA (Table 3). Therefore, a chi-square test for independence was run with the categorical variables "Family-Engineering: Yes/No" and "GPA: Low, Middle, High." However, no significant relation was determined, X^2 (2, N = 174) = 1.87, p = 0.393.

Table 3. Family Member Engineer x Participant GPA

		GPA			
		High	Middle	Low	Total
Family member who is an engineer?	No	43	45	18	106
	Yes	27	24	17	68
Total		70	35	69	174

In addition to asking whether respondents had any family members in the field of engineering, they were asked to provide the highest level of educational attainment of their mother and father. Most participants' mothers completed some college or a 2- or 4-year degree (n=100). Many also completed graduate school (n=50). About half as many completed some high school or were high school graduates (n=24). Participants' fathers had similar educational backgrounds. Most had completed some college, or a 2- or 4-year degree (n=92), and the second largest number had completed graduate school (n=52). Those who completed some high school or were high school graduates made up the smallest category (n=30). As stated above, a chi-square test for independence was conducted to determine whether participant's success, measured by their current GPA, was significantly associated with their parent's educational attainment. There was not a significant association between the fathers' educational level and the daughters' GPA, X^2 (4, N = 174) = 7.29, p = 0.127, nor the mothers' educational level and daughters' GPA, X^2 (4, N = 174) = 8.82, p = 0.065 (Table 4 and 5). However, the contingency table for mother's educational attainment and daughter's GPA included a number less than 5, and therefore a Fisher's exact test was implemented. The Fisher's exact test resulted in a *p* value of p=.059, meaning there was not a significant association between mothers' educational level and daughters' GPA.

Table 4. Mothers' Educational Background x Daughters' GPA

		GPA			
		High	Middle	Low	Total
Mothers' Education Level	High School	10	11	3	24
	College	33	46	21	100
	Graduate	27	12	11	50
Total		70	69	35	174

Table 5. Fathers' Educational Background x Daughters' GPA

		GPA			
		High	Middle	Low	Total
Fathers' Education Level	High School	13	12	5	30
	College	29	42	21	92
	Graduate	28	15	9	52
Total		70	69	35	174

Engineering Influences: Media

Although the vast majority of respondents indicated the media did not play a significant role in their career choice (n=148), those who felt it did were asked to complete an open-ended question that asked "…how did media influence your career choice?". In addition to the 26 participants who indicated media played a significant role in their career choice, 4 participants

who indicated media did NOT play significant role provided responses to the question. All written responses were read and coded based on content. The codes and associated number of responses are shown in Table 6. The single participant who indicated media had a negative influence did not offer an explanation. Non-gender related inspiration included comments such as, “Seeing contributions to the medical field by new inventions.” Gender-related inspiration included comments such as, “Saw the gap between women and men and felt motivated to fill it.”

Table 6: Media Influence on Career Choice

Code Group	# of responses
Media provided inspiration – gender-related	10
Media provided inspiration – non-gender related	8
Media showed importance of taking action/addressing issues	5
Listed a specific movie as motivation	2
Media impact was negative	1

Discussion

In response to the first research question, what do women identify as influences for enrolling in an engineering major?, we found personal interest followed by desire for a “good” career as the primary motivators of female undergraduates to enroll as engineering majors. There are many reasons someone may be interested in a particular field. Previous research has found women are more interested in engineering disciplines they perceive as helping others, such as bioengineering/biomedical engineering [39]. Additionally, computing, communications, and electrical and electronic engineering (CCEEE) disciplines have particularly low enrollment of women. A study [28] found social stereotypes, environment, and interest as the three reasons for this low enrollment. The number of responses in the current study from mechanical, bioengineering, and environmental engineering suggest women at this university follow national trends in enrollment in engineering disciplines. The fact participants claim in this study the decision is based on interest may point towards the need for pre-college interventions to link various engineering disciplines with human-centered needs/outcomes.

We also found media had a limited impact on participants overall. However, those participants influenced by media largely found portrayals of engineers and innovations as inspirational. Although media only influenced a small number of participants in the current study, it is possible increasing positive, real-world portrayals of engineers could stimulate interest, which then becomes the driving force in deciding upon a major. Similar to Beggs [41] study on how students choose college majors in general, where she found low importance given to information seeking and high importance given to interest, it is difficult to determine where the participant’s interest came from. Therefore, future research may look at what aspects of various engineering disciplines students find interesting, and where/when that interest was sparked.

Additionally, we found nearly half of respondents had a family member in the engineering field. Although this was not named as the "most important" reason they enrolled, it would be interesting to compare these results to a random sample of non-engineering majors at the university. It did not appear STEM- or arts-focused camps impacted the participants' decision on majoring in engineering as most participants attended neither type of camp. However, this again brings up the difficulty of pinpointing where interest comes from, and the unknown impacts of multiple experiences.

In response to the second research question, What role does their educational and family backgrounds play in their success, as measured by GPA?, we found a, non-significant, positive association between mothers' educational attainment and daughters' success. There was not a statistically significant association between fathers' educational attainment or family engineering background with participants' success. This may suggest having a highly-educated female role model can impact students' long-term success. Indeed, previous research has found female role models within engineering departments (i.e., faculty) play an important role in influencing the number of enrolled women [43]. Increasing the availability of pre-college and in-college mentoring programs for women may be one way to ensure accessibility to these role models regardless of family background.

It is important to note that the women who participated in this study were mostly white, with parents who had a 4-year degree or higher. They mostly came from public high schools in the same state they attend/ed university and currently had at least a 3.0 GPA. Although this sample does represent the population at the time of this study, the goals and interests represented in this sample may not align with the broader population we aim to recruit to the engineering field. Increasing diversity in engineering requires more than recruiting white women; we must look to increasing the number of engineers from all racial, ethnic, and socio-economic backgrounds. Looking towards the future, not only will we need more engineers to handle the field's projected job growth, teams with diverse perspectives may be more successful in meeting 21st century challenges [44-46].

Conclusion

The goal of the current study was to understand why women enroll as engineering majors. Additionally, this study provides avenues for future research. Female undergraduates completed a 20-question survey that asked them to identify their reasons for enrolling as an engineering major, as well as their personal and family educational backgrounds. A majority of survey participants chose engineering because they were interested in it (n=103) or because they thought it would lead to a successful career (n=46). Additionally, nearly half of the students had at least one family member working as an engineer. Interest was a major driving force for these women to choose engineering; future research may look at what sparks an interest in engineering, and how this interest is sustained. As previous research has shown, this may involve seeing engineering as a way to make a difference in the lives of others/improving society [10], [39], [28] as well as addressing the desire for a successful and stable career.

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