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Engagement in Practice: The Road to Higher Education - Is the Pipeline Half Empty or Half Full? An Analysis of Student Experiences, Perceptions and Backgrounds When Considering a Career in Engineering

Paula Davis Lampley (Women in Engineering Director)

Paula Davis Lampley is the Women in Engineering Director at the University of Cincinnati College of Engineering and Applied Science Office of Inclusive Excellence and Community Engagement. As a lawyer and engineer, Paula is passionate about advocating for inclusion and equity for women and racially and ethnically diverse students, as well as inspiring the next generation of engineers. Paula is intentional in creating programming for women faculty, staff, and students that fosters social engagement and professional growth. From her years as an attorney, Paula is thrilled to continue her research which now focuses on best practices for supporting and recruiting the next generation of women engineers. In 2021, Paula and her colleagues were recognized as the authors of the 2021 Best Diversity, Equity and Inclusion Paper in the Community Education Division for their paper "Leveling the Playing Field: A Virtual Summer Camp for Women of Color", which was presented at the 2021 ASEE Conference. Paula is passionate about sharing the connection between law and engineering. Paula spoke at the 2021 National SWE Conference and is excited to deliver her speech "From Beaker to Gavel…Engineers Make Great Lawyers" at the 2022 at National SWE Conference. Paula is excited to speak with you today and firmly believes that STEM and justice will move our country forward.

Krizia L. Cabrera-toro

Whitney Gaskins (Assistant Dean of Inclusive Excellence and Community Engagement)

Michele Mensah

Samieh Askarian

Samieh Askarian Khanamani is a Ph.D. student at the Department of Engineering Education, University of Cincinnati. She has 10 years of experience as Vice-Principal in elementary school in Iran. She has a bachelor's degree in project management Engineering from Payamnoor university and a Master's degree in Civil Engineering from Azad University. Her research area of interest lies in informal preK-12 education to strengthen the engineering pipeline.

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Introduction

As the U.S. wrestles to secure its position as the leader in global innovation and technology, there is a tremendous need to increase and diversify the number of engineers and scientists who graduate each year, commonly referred to as the "pipeline" [1]. Although the need to build the science, technology, engineering, and math (STEM) "pipeline" is well documented, the U.S. has struggled in graduating the required professionals to support the STEM workforce demand [1]. To effectively address the shortage, there is an emergent need to evaluate how high school students prepare, discover, and navigate their pathway to the engineering pipeline, and the beliefs, individuals or experiences that support or dismantle their progress. Research indicates that career choice is often influenced by intrinsic factors such as students' prior experience; social support; self-efficacy and outcome expectation. Specifically, students' career choice may be cultivated by the exposure to subject matter; the influence of family, peers, and teachers; the belief and perception of their capability and their overall expectation [2]. To better understand students' thought process related to pursuing a STEM career, this study evaluates the responses of 109 high school students to survey questions grounded in the following six themes: (1) Engineering Related College Preparatory Classes; (2) Engineering Influencers; (3) Summer Engineering Enrichment Opportunities; (4) Personal Knowledge of Engineers; (5) Thoughts and Concerns about Studying Engineering; and (6) Beliefs Regarding Engineering and Science Fundamentals and Concepts. The results of this study may provide the most effective methods to support, guide and inspire students to pursue engineering careers with an aim to increase the pipeline.

Theoretical Framework

To increase and diversify the engineering pipeline, it is important to clearly understand how students choose or avoid the selection of a particular college major or career. This paper is grounded in social cognitive career theory (SCCT) which examines students' decisions about a particular field of study or career [2]. The SCCT framework focuses on the interconnection of three key constructs: interest, self-efficacy, and outcome expectancy that generate aspirations for one's career choice. Specifically, SCCT evaluates students' perception of their abilities, career expectations, academic performance, influencers, as well as environment which may inspire or detract from academic or career goals [3]. Derived from the SCCT framework, a survey metric was designed to analyze students' support, academic and pre-college experiences, beliefs, and familiarity with engineers, to determine if such factors affected, directed, or detracted from their decision to study engineering.

Participants

Researchers employed at the University of Cincinnati, utilized an online survey tool to collect data from 109 high school students enrolled in virtual engineering summer camps hosted by the institution. Student applications disclosed the following demographics: gender: 61% identify as women, 38.5% identify as men and less than 1% did not disclose. Race and Ethnicity: 42% identify as white, 30% as Asian, 21% as Black/African American, 4% as two or more races and 3% as Hispanic/LatinX. All demographic data was self-reported and collected anonymously without any identifiers.

Findings

A mixed method of qualitative and quantitative metrics was utilized to gather survey data. To determine STEM preparedness, the students were asked "Which math and science courses have you taken, including those you plan to take before high school graduation?" (Figures 1A and 1B). A total of 66 women and 42 men participated in the survey (1 student did not disclose their gender).

The P-value for each of the math classes (Figure 1A) is a range of .263 to .981. Consequently, the P-value shows that there is no difference between the math classes taken by men and women. The P-value range of .454 to .748 for science classes (Figure 1B) indicates that there is no difference among those classes taken by men and women. However, a P-value of .000 for physics, shows a significant difference that men take more physics classes than women.

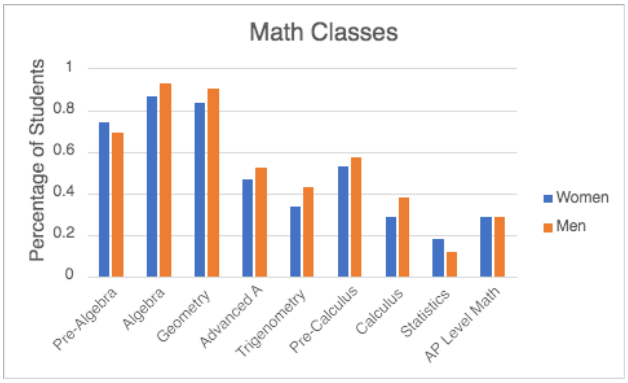

Figure 1A. Participants' responses to the question "Which math courses have you taken, including those you plan to take before high school graduation?"

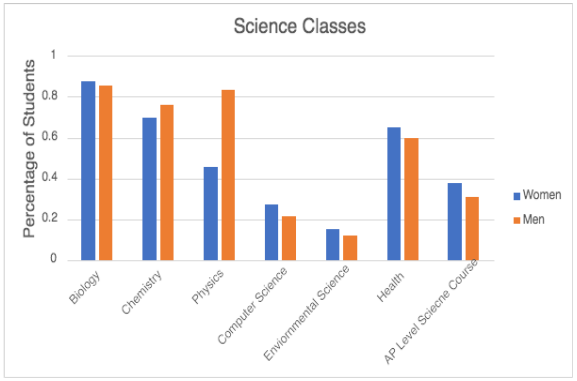

Figure 1B. Participants' responses to the question "Which science courses have you taken, including those you plan to take before high school graduation?"

Influencers play a significant role as students make decisions regarding a career choice. Figure 2 represents participants' responses to the question "Who encouraged you to consider engineering or applied science?" As revealed in Figure 2, parents are the largest influencers; however, based on the P-value of .629 to .847 there is no significant difference between the encouragement students receive from parents and teachers to study engineering or science. Although not significantly different (P-value of .094), there is a difference in the rate guidance counselors encourage men to enter STEM versus women.

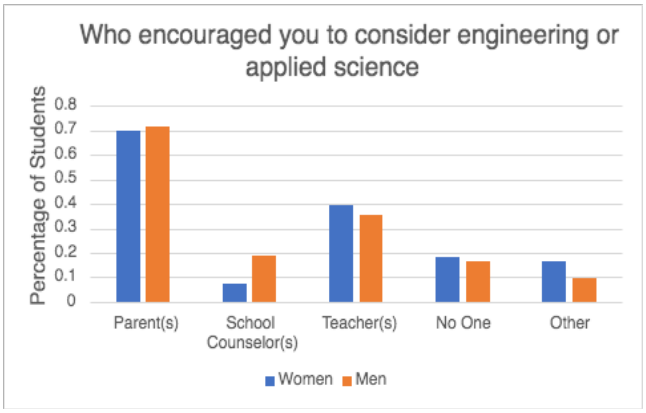

Figure 2. Participants' responses to the question "Who encouraged you to consider engineering or applied science?"

When asked if participants engaged in engineering related summer camps prior to attending the camp hosted by University, 73% of women indicated they had not participated in such camps, while only 45% of men indicated that they had not participated in at least one camp.

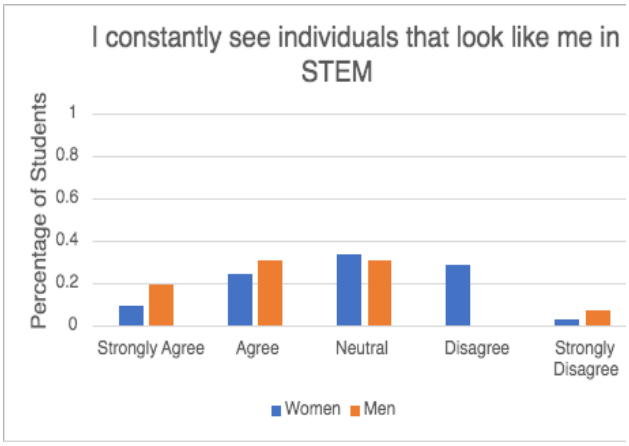

Figure 3A. Participants' response when asked to rate the following statement: "I constantly see individuals that look like me in STEM".

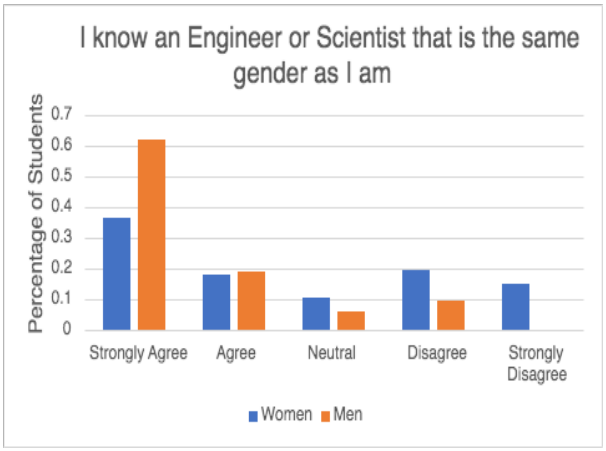

Figure 3B. Participants' response when asked to rate the following statement: "I know an Engineer or Scientist that is the same gender as I am."

When asked to respond to the statement "I constantly see individuals that look like me in STEM," Figure 3A indicates that only 9% of women strongly agreed, while 19% of men strongly agreed and 29% of women disagreed. When asked to respond to the statement "I know an Engineer or Scientist that is the same gender as I am," Figure 3B indicates that 36% of women strongly agreed, while 62% of men strongly agreed.

In following the tenants of SCCT, it is important to understand a student's concerns or beliefs when considering a career. Students were asked the following open-ended question "What are your concerns when considering studying engineering or applied science in college?" Of special note, only 25 (23%) out of 109 students (14 women and 11 men) indicated that they had

concerns. Of the 25 students who responded, the following six themes arose: racism and sexism; difficulty of workload; unhappiness and level of stress; tuition fees; not smart enough; and finding a good job (Table 1 below).

In evaluating the responses of the 25 students, it was noted that none of the women shared a concern about securing a job, while 2 men (18%) indicated concerns about securing a job when graduating; 5 women (36%) and 2 men (18%) are concerned with the difficulty of the course load. Not surprisingly, there were no concerns from males about racism or sexism in the workplace. To the contrary, 2 women (14%) disclosed concerns about racism or sexism. Further review of the responses indicates that 3 women (21%) and 3 men (27%) are concerned with their perceived lack of intelligence. Regarding tuition, 1 male (9%) and 1 female (7%) shared concern about the cost, and 1 male (9%) and 1 female (7%) indicated that they are concerned with stress and unhappiness associated with studying engineering or science.

Theme	Concerns
Racism and sexism	"I am concerned that I may not be cut out to be a woman in the stem field. It is a field of work that is dominated by men, and I fear that I may be overlooked, but I am absolutely willing to give my best effort and do everything I can to succeed." "I am concerned that I might face both sexism and racism when it comes to the field."
Difficulty of workload	"I am concerned about the workload and the difficulty of the courses I will have to take in college." "That it might be too much/too hard to handle in college."
Unhappiness and level of stress	"That it will be stressful." "If I'll able to make myself proud and if I'll be happy in my field."
Tuition fees	"I am concerned about the tuition prices."
Not smart enough	"Not feeling like I fit in, not feeling like I'm smart enough to be in the classes." "Not being knowledgeable enough, falling behind."
Finding a good job.	"Stress from academic workload and finding internships/jobs." "It's a very popular major choice and that could lead to a lot of competition for jobs."

Table 1. Participants Responses to Question: What are your concerns when considering studying engineering and applied science in college?

To address participants' understanding of real-world applications of science fundamentals and concepts, students were asked to respond to the statement: "I believe science, mathematics and technology have real world applications." Figure 4 indicates that both men and women feel strongly about the concept of science, mathematics and technology having real world applications.

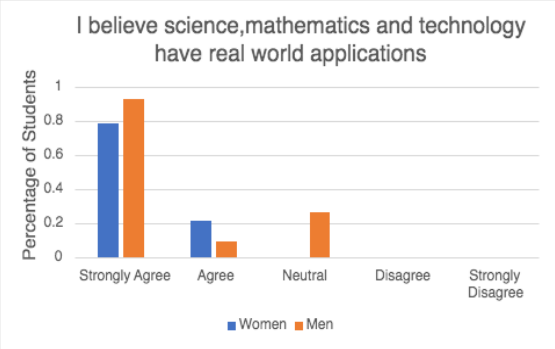

Figure 4. Participants' responses when asked to rate the statement "I believe science, mathematics and technology have real world applications."

Discussion

Evaluating students' beliefs, perceptions, and experiences as they navigate their way to or away from engineering or science, may inform the methods used by high schools and universities to inspire, encourage, and prepare students to embark on STEM careers, with the goal of impacting the increase in the pipeline.

According to the P-value for math and science classes (Figure 1A and 1B), there is no significant difference in the number of math and science classes taken by men and women. However, the P-value relative to physics classes, indicates that women lag men in the number of physics classes taken. Of notice, 70% of men and women indicated that parents act as significant influencers, and over 35% of students indicated that teachers influenced them to consider studying engineering or science. Figure 2 suggests that counselors encourage men to consider studying engineering or science more than women. Consequently, counselors should be advised to speak with all students about studying engineering or science. Counselors should also be instructed to share the importance of taking physics for those interested in studying a STEM major. For those students who indicated that "no one" influenced them, one may hypothesize that social media, television, or an engineering-related event may have inspired them.

The data regarding STEM related pre-college programs indicates that there is a definite need to inspire women to attend pre-college engineering programs and summer camps. Moreover, research indicates that exposure to same-sex role models can bolster women's identification with STEM. [4] With 29% of women disagreeing with the statement "I constantly see individuals that look like me in STEM", and 20% disagreeing with the statement "I know an engineer or scientist that is the same gender as I am", high schools and colleges have an opportunity to create mentorship programs and other activities where women students are exposed to women engineers and scientist.

It is important to note that only 25 (23%) of the 109 respondents indicated that they have concerns when considering studying engineering or applied science, which represents a small sample size. When questioned about concerns, women are concerned with sexism and racism, while men are not. Women and men are concerned with their level of intelligence to succeed as an engineering student. Both women and men are concerned with their level of happiness and

stress. This result brings to light the need for more information regarding women's understanding of engineering in addition to encouraging them to study STEM disciplines [5]. In addition, studies show that values are especially important in students' choices to become engineers. To increase persistence rates, we must focus on values, especially by helping students connect their personal identities to engineering identities [6]. Survey data revealed that students are concerned with the cost of tuition and men are concerned with securing a suitable job. As a result, pre-college workshops focused on financial aid and scholarship resources, as well as STEM career opportunities may be beneficial to high school students.

Limitation and Future Work

This study represents the views of 109 high school students residing in ten states, which may be considered a small survey size. Moreover, the survey results were generated only from students who attended a summer engineering camp at a single institution. For future studies, it may be instrumental to consider a larger pool of survey participants and evaluate survey results by state, and school orientation (public, private or independent). To collect more actionable data, future surveys should include "forced choice" survey questions, thereby eliminating "no one" "don't know" or "other" responses. To better identify students' perceptions related to "science" "mathematics" "technology" having real-world applications (Figure 4), future studies may be enhanced by isolating each concept and asking students to rate each concept separately.

An expanded analysis of participants' survey responses with respect to their race and ethnicity may provide insight into cultural norms, beliefs or expectations that may affect decisions regarding studying engineering. A longitudinal study may be implemented to track participants' high school class selections, summer STEM experiences, college major, intent to major and persistence to major in engineering or other major. The results of the study are insightful and may inform the way high schools, colleges, and organizations support, guide, and inspire students to become engineers.

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