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Beyond Math Readiness: Understanding Why Some Women Pursue Engineering

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Abstract

Students decide to study engineering for many reasons: they may be interested in math and science, enjoy tinkering with things, or have been encouraged to study engineering because of their academic ability. Women students often study engineering because of their math and science abilities. In the literature, interest and success in math and science are often considered the most critical factors influencing students' decision to study engineering. In many engineering programs, students need to start their undergraduate education in Calculus 1 to be on track in the major. In 2023, student readiness is significantly different because the COVID-19 pandemic significantly impacted math and science achievement. More incoming engineering students than ever placed below Calculus 1 and are navigating the impact this has on their engineering major and coursework trajectory. Even with the added barrier of being categorized as pre-math-ready or beginning in Pre-Calculus in their first semester, students continue to pursue engineering. What influences their decision to study engineering? This paper examines the factors influencing women engineering students' decision to pursue engineering when they are characterized as pre-math-ready. We interviewed engineering students in Calculus 1 during the second semester of their first year at a large southeastern university. The interview covered many topics about math, COVID, and engineering, but all the students discussed their desire and decision to pursue engineering. Using a life-course perspective developed for engineering students, we identified the factors influencing pre-math-ready students' decision to study engineering. Students discussed the strong influence of role models and family members who are engineers, the exposure to engineering through high school programs, and the desire to help people, which led them to study engineering. Students notably did not discuss academic achievement or math and science interest/proficiency as catalysts for their decision to pursue engineering. This work can help researchers and practitioners better understand how students who do not have high performance in math and science decide to pursue engineering. Future work can focus on investing in and improving the factors identified by this study.

Introduction

Math readiness has historically been considered one of the most critical predictors of engineering student success in the major [1]. A significant amount of the messaging around engineering focuses on the idea that engineers need to be "good at math and science" [2]; however, this messaging can be harmful and deter students interested in engineering if they do not have the math background expected. Students often pursue engineering because they have a math identity – this means they perform well in math, are recognized as good at math, and are interested in math [3]. For women students, math self-efficacy significantly influences their decision to study a math-related major [4] or stay in an engineering major [5]. However, a population of women students classified as pre-math-ready may not have a math identity or high math self-efficacy but still choose to pursue engineering.

In 2023, there are significantly more pre-math-ready engineering students than ever before. The increasing number of pre-math-ready students is a product of the COVID-19 pandemic. The global pandemic halted education in March 2020, and schools and teachers needed to adapt to the best of their ability [6]. Due to the pandemic, standardized tests and college entrance exams could no longer be used for admission or placement. Higher education institutions found alternative ways to evaluate student's academic preparation to admit them into schools and majors and place them into classes. The movement away from standardized tests is a movement toward equity [7]; however, colleges were not expecting the change in students' mathematics placement without standardized tests. More and more schools have used alternative assessments, like the ALEKS assessment, to place students into classes, but relying solely on test scores often underplaces students into developmental math classes [8].

The institution in this study used a placement algorithm before COVID that included high school GPAs, SAT scores, class rank, etc., to place students into math classes. Pre-COVID, approximately 2-3% of incoming engineering students were placed below Calculus 1 and deemed pre-math-ready. However, 26% of incoming engineering students in Fall 2022 were considered pre-math-ready, and the percentage grew to 28% in Fall 2023. The change in math readiness is not unique to this institution [9], and it is therefore important to understand how to support students, specifically in a field like engineering, that already experiences high attrition.

Due to a rigid curriculum, engineering students taking Calculus 1 in the second semester of their first year will be behind in most engineering majors and will likely take longer to declare their major and complete their degree [10]. However, even with the added barriers, pre-math-ready students still choose to pursue engineering. Generally, there are a few common reasons students decide to study engineering. The factors are often related to an interest or proficiency in math and science, an enjoyment of tinkering, or a desire for multiple career options [11]. Women students, specifically, decide to study engineering because of their strong math and science abilities. Either by accident or on purpose, they find that engineering nicely combines their math and science abilities [12]. In light of the disruptions caused by COVID, an increasing number of students may have unique experiences and needs as they navigate the math pathway leading to engineering. Since a significant factor in pursuing engineering is interest and proficiency in math, there is space to understand how students who do not have math proficiency decide to study engineering. This discrepancy highlights the need to understand why pre-math-ready students choose to pursue engineering.

The purpose of this study is to characterize the factors that influence women students' decision to study engineering when they are determined to be pre-math-ready. The following research question will guide the study.

RQ: How do women students decide to study engineering when they are pre-math-ready?

Literature Review

Prior literature has described how women and girls are encouraged to become interested in STEM and engineering, and other work has focused on the relationship between math readiness in engineering and factors that influence students' decisions to pursue engineering. Math readiness and the decision to pursue engineering are not mutually exclusive; one commonly influences the other. However, little work has focused on women students who are not math-ready and the factors that influence them to study engineering.

Gender in Engineering

Traditionally, fewer women and girls have pursued engineering compared to men [13]. Recent research suggests that this gender gap in engineering may be attributed to differences in self-efficacy and interest levels. For instance, a study by Buontempo et al. [14] surveyed girls enrolled in a high school engineering course and found that girls generally exhibit lower self-efficacy and interest in engineering than boys. Interestingly, another study by Bystydzienski et al. [15] showed that high school girls who participated in a 3-year intervention program significantly boosted their interest in engineering. However, despite their increased interest and academic preparedness, many low-income minority women chose not to follow an engineering path. Financial constraints, a lack of social support, and fear of failure primarily influenced their decision. Moreover, prior research indicates that stereotype threat can cause gender disparities in math performance, further complicating their pursuit of engineering [16].

Women already have a difficult time in engineering by not being a part of the dominant group. Engineering is known to have a chilly climate for students in the non-dominant gender group. For example, studies have highlighted the hidden curriculum of STEM course syllabi that promote masculine thinking and the idea that women are incompetent [17]. Additionally, to gain acceptance in engineering, many women need to 'undo' their gender to help maintain the accepted, masculine environment [18]. Acknowledging that gender is a social construct, the term 'woman' is used in this study to represent all women who fall on the woman gender identity spectrum [19]. Anyone who does not identify as a man is considered to be in the non-dominant group in engineering and may not identify with the masculine culture experienced in engineering [20], [21].

Math Readiness and Engineering

Calculus eligibility is often considered when discussing math placement for engineering students. Calculus-eligible students can register for Calculus 1 during their first semester and stay on track in their major. Calculus eligibility is often linked to retention in engineering; one study found that students placed in Calculus 1 are 6.15 times more likely to graduate from engineering within six years compared to their calculus-ineligible peers [22]. However, Bowen et al. also found that calculus eligibility is not a stand-alone predictor for success in engineering; when they controlled for calculus eligibility, they found that achieving good grades and maintaining above a 3.0 GPA are essential to success in engineering [23]. Similarly, recent literature found that calculus-ineligible students who are successful in their first math class (e.g., Pre-Calc) are just as likely to graduate as students who begin in Calculus 1 and are less successful [24], [25]. The increasing amount of literature focused on success in a math class over math placement shows there is more work to be done to understand the experiences of pre-math-ready engineering students.

Impact of COVID

The increase in pre-math-ready engineering students is a direct result of the COVID-19 global pandemic. COVID disrupted education and significantly impacted students' mathematics development compared to language arts development [9], [26]. Initial reports from the early pandemic (2021) stated that elementary school students could have lost five to ten months of learning in mathematics, with potentially similar ramifications for middle and high school students [27]. In addition to learning loss, adolescents had significant issues staying motivated and developing necessary academic skills while learning from home [28], [29]. Students' academic readiness is expected to differ because of COVID, and higher education must adapt [30].

Engineering Curriculum

The current engineering curriculum and prerequisite chains are barriers for students who are not 'math ready.' Studies have focused on individual program initiatives to address the mathematics curriculum barrier. For example, Clemson changed their math sequencing to allow first-year engineering students to take Calculus 1 during their second semester and stay on track for the major. They accomplished this by changing the calculus prerequisite for their second-semester engineering class to a corequisite. This change improved engineering students' retention and showed the importance of students starting in a math class that they are ready for [31]. Moving mathematics into engineering departments to create engineering-specific math classes is a popular curriculum change made to support students; however, this change may not be supported by math departments. One paper studied two programs that developed an engineering-specific calculus course. Of the two programs, one sustained the engineering math class, while the other terminated it. The program that ended the class did not clearly distinguish between engineering and non-engineering calculus within the math department, which led stakeholders to have limited buy-in [32]. Major-specific mathematics classes are not unique to engineering. Many colleges have begun incorporating math pathways for different majors to learn skills relevant to their future careers [33].

Another well-known math-related curriculum initiative is the Wright State Model, which includes a first-year engineering math course taught by engineering faculty; the course replaces the prerequisites for typical sophomore-level engineering courses and has led to higher retention in engineering [34]. Furthermore, West Virginia University has implemented an intervention program to assist students who withdrew from Calculus 1. The students who withdrew from calculus were eligible to enroll in a class meant to fill the gaps of Pre-Calculus content and other knowledge needed for calculus so students could prepare to reenroll the following semester [35]. Several institutions are committed to changing the curriculum to support pre-math-ready engineering students better; however, no universal curriculum changes are happening.

Factors that Influence Engineering Major Choice

The field of engineering education has investigated many factors that influence students' decision to pursue engineering. Godwin et al. found that math and physics identities and the belief that science can positively change the world influenced students' choice to study engineering. In Godwin's study, math and physics identities consist of performance, recognition, and interest; however, performance alone was a negative predictor of engineering choice. Recognition and interest helped positively predict engineering choice [3]. Similarly, one study found that an interest in math and science was often associated with an interest in engineering for rural students [36]. Math and science interest and performance are often considered alongside engineering major choice, but from these studies, performance may not be as important as interest.

Engineering choice is also associated with high school math classes. Recent literature found that students' decisions to pursue engineering were not predicted by the number of math and science courses offered at a high school; instead, they highlighted how other factors could contribute to engineering major choice across different demographics [37]. This was some of the groundwork for Main et al.'s conceptual model used in this study. Cruz & Kellam found that enjoyment of tinkering, a desire to be creative, and a need for multiple career options were predictive of engineering major choice along with math and science interest [11].

The decision to study engineering and succeed in the major is rarely separated from an interest in mathematics and math class placement. Due to the impact COVID-19 has had on students' academic readiness, there is a need to understand more about pre-math-ready students pursuing engineering. Pre-math-ready engineering students have different math competence compared to their peers, and their interest in math was likely affected by the difficulties of math instruction during the pandemic [38]. This is especially important for women students who face stereotype threats in engineering. This warrants the need to study the factors influencing women students' decisions to study engineering when they are pre-math-ready.

Conceptual Framework

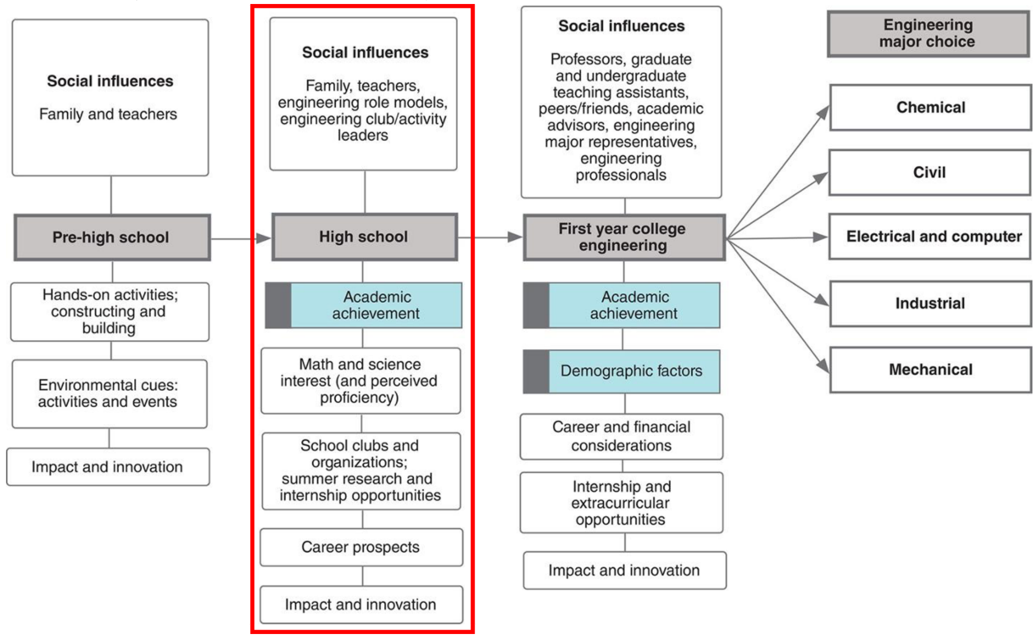
A life course perspective connects the lived experiences of individuals to their stage and development in life [39]. Recent work in engineering education used a life course perspective to develop a conceptual model, which is the framework for this study. Main et al. used a life course perspective to understand different factors across life stages (pre-high school, high school, and first-year engineering) that contribute to engineering students' major choice [40].

Social influences, like family members and teachers, are important and prevalent for engineering students throughout their lives. During the pre-high school stage, other influences include hands-on activities and events. During the high school stage, academic achievement, math and science interest, and engineering opportunities become important factors. During the first-year engineering stage, other factors are important in addition to academic achievements, like financial considerations, demographic factors, and internship opportunities. Across all life stages, impact and innovation to positively contribute to society with cutting-edge technology are critical. The different life stages contribute to engineering major choice. A complete diagram of the conceptual model can be found in Figure 1.

This conceptual model will be used as the framework for the study. The conceptual model was developed to understand the choice of engineering major at an R1 institution similar to the one in this study. Since the model was developed in a similar context, it is likely transferable for the context of this study. Although the conceptual model crosses multiple life stages, the factors identified in this study will follow the high school stage since participants extensively discussed that stage. Additionally, the model was created to understand major choice in specific engineering disciplines, but this study will focus on engineering major choice generally.

Figure 1

Conceptual Model from Main et al.'s study [40].



Note: This study focuses on the high school life stage from the conceptual model. The figure was adapted to highlight this portion of the model.

Methodology

Qualitative researchers study things in their natural setting to make meaning of phenomena as people experience them [41]. A common type of methodology in qualitative research are case studies – a case study allows researchers to study a phenomenon in its bounded context [42]. This project used a case study to understand the factors influencing women students' pursuit of engineering when they are pre-math-ready. This study's case is bounded by the type of university and type of student. The university referenced is a large research university where the engineering student population represents about 30% of the undergraduate population, and about 21% of engineering students identify as women. At this institution, engineering students should enroll in Calculus 1 during their first semester to be on track in their major. The participants of this study are first-year engineering students enrolled in Calculus 1 during their second semester, so they are not on track for the engineering major. Since the number of pre-math-ready engineering students has grown post-COVID, the case likely represents a similar phenomenon at other large engineering programs.

Participants and Sampling

Since the case involves several individuals situated in the same context [43], purposeful sampling was used to find participants for the study [44]. The participants in the study are first-year engineering students at a large R1 university enrolled in Calculus 1 during their second semester. After receiving approval from the IRB, we collaborated with the General Engineering Advising Coordinator at the university to contact all first-year engineering students enrolled in Calculus 1 during the spring semester. If students were interested in being interviewed, they were asked to fill out a screening questionnaire to gather background information. Students needed to be an engineering major 'behind in math' and in high school during the peak pandemic school years to be eligible to participate. Students who filled out the screening questionnaire and met the eligibility criteria were contacted to schedule an interview.

In this study, one participant identifies as genderqueer and is, therefore, part of the non-dominant group in engineering. Recent literature has called for a paradigm shift to lift all voices in engineering, not just those who identify as cisgender [45]. For this reason, we chose to include this participant's voice in this study.

Data Collection

The primary forms of data collection for this study were: interviews, background information, and memos written directly after the interview. The findings reported in this paper are part of a larger study interested in understanding engineering students' math experiences during COVID and a holistic view of their choice of major.

The screening questionnaire asked students to report their current math class, planned major, intended major when they started college, demographic information, and questions about their high school years. The participants self-described their gender and racial/ethnic identity, so the descriptors used in the table are the participants' words. Six people were included in this study; their information with pseudonyms can be found in Table 1.

Table 1

Participant Information

Name	Gender Identity	Race/Ethnic Identity	Major
Claire	Female	White	Aerospace Engineering
Skylar	Female	White	Biological Systems Engineering
Kiara	Female	Race - African American / Black Ethnicity - Hispanic and Caribbean	Biomedical Engineering
Maria	Female	Latina	Computer Engineering
Jaya	Female	Indian (Asian)	Aerospace Engineering
Shay	Genderqueer	White	[removed for anonymity]

Note: Students were asked to self-describe their gender and racial/ethnic identity.

Semi-structured interviews were conducted with each participant and lasted for about 25 minutes. We developed the interview protocol to cultivate a holistic view of engineering student experiences during COVID and learn more about their major choice. The questions were open-ended to allow participants to talk generally about their experiences. Since the interviews were semi-structured, we followed up with specific questions to gain clarity and insights into their responses. The participants consented to the interviews being recorded, so all the interviews were recorded on Zoom and transcribed by Rev.com.

After each interview, I (the first author of this paper) filled out a structured memo to record my thoughts and interpretations that may not come through on the recordings or in the transcript. The memo included a summary of the main ideas I was interested in investigating and a section where I could provide my interpretations of the interview.

Data Analysis

Although the interview protocol covered topics about students' COVID experiences and their experience in engineering at the university, the students talked extensively about the factors that influenced their decision to study engineering. Therefore, the analysis focused on those factors.

The interview transcriptions were analyzed through two cycles of coding: initial coding and deductive coding. Initial coding is the process of breaking down the transcripts into parts and comparing similarities and differences across the parts [46]. From this process, I found that students consistently discussed factors influencing their decision to pursue engineering. Since students consistently discussed the factors that influenced their decision to pursue engineering, that was the focus for second cycle coding. The transcripts were coded deductively during second cycle coding to align with the conceptual framework. The conceptual framework includes factors at various life stages contributing to engineering students' major choice. The codes are the factors at the high school stage: social influences, academic achievement, math and science interest (and perceived proficiency), school clubs, career prospects, and impact and innovation. The codebook with relevant themes can be found in the results section. Throughout the interview process, I wrote memos to summarize what students were saying and my interpretation of the interview. Having a structured memo process made it easy to transition from the initial coding to the deductive coding cycle because I was already considering the emerging themes.

Trustworthiness

Reporting on the quality, credibility, and validation of qualitative research is the best practice to ensure the study's trustworthiness [47]. In engineering education, Walther et al. [48] provide validation strategies to ensure the quality and trustworthiness of qualitative research.

Theoretical validation of a study should reflect the complexity of the lived experience under investigation. This can be validated through the use of an opposing case analysis. As can be seen in the findings, different factors had opposing narratives emerge. Considering alternative or opposing perspectives is particularly important to ensure the reliability of a case study [43]. Communicative validation of the study should connect the author’s interpretations to the literature. We discussed the interviews and how we interpreted what the participants said in the context of the conceptual framework and already-established literature in the field. Finally, process reliability should ensure that data gathering is done dependably. I had a process established in the first interview, and I followed it for all subsequent interviews, which included recording the interviews and filling out a structured memo directly after the interview ended. Ideally, I wanted to collaborate with the participants to share the transcripts and findings with them [44]; however, it was beyond the scope and timeline of this project.

Positionality

Our positionalities and identities as researchers inevitably shape our analysis and approach to research [49]. The engineering education field has established that positionality is operationalized as reflexivity, and researchers should identify and acknowledge their biases and experiences to improve research quality [50]; therefore, reflecting on positionality and biases is critical to our roles as researchers. We are both women in the field of engineering education, have backgrounds in engineering, and experience working as engineers. We both placed beyond Calculus 1 and were considered 'math ready' in college; however, we both have experience tutoring students in mathematics, with the first author having more explicit experience through working with a STEM education non-profit at four high schools as a supplemental math and science educator. Through experiences as educators, we have both informally talked to many students about their math experiences during the COVID-19 pandemic and lockdown. Based on our experiences, we collectively are interested in understanding the impact of COVID-19 on math readiness and how we help students succeed in math and engineering. We are particularly interested in making the field of engineering more inclusive and have concerns about current trends. The second author chose to study engineering for reasons that align with the findings from this study, and the first author chose to study engineering because of her math and science abilities. Reflecting on our experiences as students in electrical engineering and biomedical engineering, we worked intentionally to minimize our biases and assumptions about the participants' experiences from our own experiences and our work with students. Additionally, this work is part of a larger study also evaluating institutional data and engineering major trends that we have not explored in this paper but may have influenced how we thought about participants' answers.

Findings

The findings for this paper focus on the factors that influence women students' desire to pursue engineering when they are characterized as pre-math-ready. The interview protocol asked about COVID experiences and the impact on their math skills. However, in the interviews, students talked extensively about the factors influencing their decision to study engineering, so that became the focus of this paper. The codebook below highlights the factors that emerged through the interviews and their alignment with the conceptual model.

Table 2
Codebook

Code	Explanation
Social Influences	Participants discussed social influences, such as family members or role models, that encouraged them to pursue engineering.
School Clubs and Organizations	Participants discussed their involvement in engineering clubs or classes, influencing their decision to study engineering.
Career Prospect	Participants talked about a specific career goal they have, which is achievable by majoring in engineering.
Impact and Innovation	Participants shared their desire to impact others through their engineering job.

Social Influences

When participants described why they chose to study engineering, family influences and role models consistently came up. Multiple participants mentioned having family members who are engineers, so they wanted to pursue engineering to follow in their footsteps. For example, Jaya always knew she wanted to do engineering because of the interests she shares with her dad,

> So I've kind of always known I wanted to do engineering. Growing up, I loved puzzles. I loved just solving things. And my dad's a mechanical engineer, so I kind of grew up taking... A lot of the things he's interested in, I now take interest in, just because he and I were so close.

Similar to Jaya, Maria expressed how she was influenced to study engineering by her dad's work in IT. Since Maria's dad studied computer science, she knew that she wanted to do something with computers,

> But my dad, he did computer science and he works in IT, so I was very influenced… I think because of my dad, I was like, "Oh, I'm going to do something in computers," and then I wanted to really do machine learning. So, then that's why I decided on computer engineering.

Jaya and Maria have family influences, or role models, that got them interested in engineering, and they did not mention their interest or performance in math.

Claire talked about how studying engineering, specifically at the university included in this study, was something everyone in her family did. Her dad studied engineering at her institution, and her grandma likes to tell her about cousins and extended family studying engineering at the same institution. Although Jaya, Maria, and Claire all talked about family influences that helped them decide to study engineering, they spoke about those influences differently. Jaya and Maria's tone showed how much they admired their dads, who are engineers, and having shared interests was important to them. Adversely, Claire's tone conveyed a different view on her familial influence; in Claire's family, studying engineering seemed like an expectation, and Claire rolled her eyes at this. The difference between Claire's familial influence and Jaya's and Maria's shows that family members can positively encourage women to study engineering or make studying engineering an expectation.

Wanting to be like family members may encourage students to study engineering; however, that was not the case for Kiara. Kiara originally wanted to study medicine but chose not to because her older sister went into medicine. She said that she was always compared to her sister and wanted to study something different from her, "But my sister went that track, and my whole life I was always compared to my sister. So I was like, I can't do the same thing. And so, I started looking into engineering." Kiara used her concern about being compared to her sister as the reason she chose engineering.

Aligned with the Social Influences factor described in the conceptual model, family members and role models who are engineers encouraged women to pursue engineering. However, some influences encouraged students away from one field and into engineering. Various social influences contribute to pre-math-ready students' decision to study engineering.

School Clubs and Organizations

Some participants expressed that their interest in engineering was influenced by the opportunities they had in high school. High school opportunities align well with the School Clubs and Organizations factor described in the conceptual model. If students are exposed to engineering early on, they may better understand what they want to pursue after high school.

Shay is interested in studying engineering because of their interest in robotics. Shay got interested in robotics through their high school's engineering club, influencing their decision to study engineering. They had the experience of being the mechanical lead for their robot in high school, and they thought their friend, who was the electrical lead, was also doing cool stuff, and that helped them pick their engineering major discipline. Although Shay is glad they participated in engineering in high school, it was not something they were planning to do. Shay describes why they participated in the engineering club in high school, "My mom forced me to do it because she said it would be good for college. I begrudgingly did it and I really enjoyed it, so I'm glad she made me do it." Although Shay wasn't excited about joining the engineering club, it opened doors to show them a potential college major.

Similarly, Claire was able to engage in engineering classes in high school, but she had to drive herself all the way there. The engineering class was only an option at a high school across town,

> I was at two different high schools, which was a little weird because we have my high school, and then we have a fancy, rich kid high school that has all the fun programs they have, like a little engineering class.

Although the logistics of participating in the engineering class were challenging, Claire enjoyed learning CAD, working on projects, and engaging in engineering teams. Claire is pursuing aerospace engineering, and she stated how getting to build rockets in her engineering class cemented her interest in aero; she said: "So I was like, you know what? I think this is something I could like do for the rest of my life."

Jaya also had the opportunity to participate in engineering classes in high school, and she is grateful for the opportunity because it helped her decide to study aerospace engineering,

> Luckily my high school offered engineering classes. So I took the engineering classes in high school. I loved it. I figured out I wanted to do aerospace just because it's just fascinating. Rockets and space and discovering new things every day, it was just so fascinating to me, the fact that it's not stagnant, the fact that every day you're learning something else.

Shay, Claire, and Jaya had positive engineering experiences in their high schools that helped them decide to study a specific engineering discipline. Interestingly, Jaya and Claire have parents who are/were engineers, so they likely had social influences during their pre-high school stage, encouraging them to get involved in engineering early on. Alternatively, Shay's mom was the one who made them participate in the engineering class, which helped them decide to study engineering.

Career Prospects + Impact and Innovation

Although not as prominent, some participants described their decision to study engineering because they wanted to help people. Helping people is not one of the factors in the conceptual model, but we interpreted it as the combination of Career Prospects and Impact and Innovation.

Students described their desire to help people in the future through engineering. After explaining how water is vital to life, Skylar described her future engineering goals, “So I want to start my own company to like, I guess, help with ground groundwater depletion or do research that helps influence policy. [I want] to make more laws that affect that or help minimize that [groundwater depletion].” Skylar’s desire to do something bigger than herself was part of why she decided to study engineering, specifically biological systems engineering. As stated previously, Kiara’s interest in engineering was because of her interest in medicine, and she also talked about how she wanted to help people through medicine. She initially considered studying chemical engineering to work on vaccines but realized biomedical engineering was more interesting.

Kiara and Skyalr’s desire to help people in their careers influenced their decision to study engineering, aligning with the conceptual model's Career Prospects factor. Skylar specifically saw engineering as a way to start a company or work to make policy changes. Similarly, the desire to help people speaks to the Impact and Innovation factor described by the conceptual model.

Discussion

The findings from this pilot study and the preliminary analysis align with multiple factors from the conceptual model. Pre-math-ready engineering students talked about varying factors influencing their decision to pursue engineering. They spoke about Social Influences, in the form of family members and role models, School Clubs and Organizations, with their involvement in engineering classes, and Career Prospects and Impact, by describing their desire to help people. They did not discuss academic achievement or math and science interest/proficiency as catalysts for their decision to pursue engineering; this contradicts the literature in the field.

One of the most prominent factors that influenced students' decision to study engineering was having a family member who is an engineer. Engineering family members pass on engineering knowledge, interests, and aspirations to students interested in studying engineering [51]. Family members who are engineers become role models for students who decide to pursue engineering [52]. Unfortunately, not everyone interested in engineering will have a family member who is an engineer, so there is a need to develop role models in other ways. Mentor programs have been successful in undergraduate students' persistence and interest in STEM [53]. There are likely similar benefits to incorporating an engineering mentor program at the high school level to get students interested in engineering as a career. Role models benefit students beyond developing an interest in engineering; role models are particularly important for women and other underrepresented minorities studying STEM and engineering. It has been consistently found that underrepresented minority (URM) students benefit from seeing someone who looks like them in the workplace to support their decision to pursue engineering, which also encourages their success and persistence [54], [55]. A recent study found that at developmental transition points, women mentors encouraged women’s belonging and retention in engineering, as well as their self-efficacy and career aspirations [56]. Considering the conceptual model, social influences such as family members are present throughout an engineering student's journey, not just at the high school stage. Therefore, including engineering mentors throughout students' schooling can help students get interested in engineering.

In addition to family members and role models, students cited their high school engineering experiences as an essential factor that helped them decide on engineering. The past decade has seen an increase in engineering education for middle and high school students, likely because of states aligning with the Next Generation Science Standards that came out in 2013, which include engineering design at all grade levels [57]. Many students thought they were interested in engineering, so they took an engineering class, which solidified their interests. This aligns with a study that found students who participated in a pre-college engineering course were twice as likely to want to pursue engineering as a career [58]. If students are exposed to engineering in high school, they are more likely to pursue engineering as a career; however, if students' only bridge to engineering is through math, they may be less likely to study engineering, especially if they are pre-math-ready. It is important to encourage and support women students with programs and resources at pivotal times to increase their interest in engineering [15]. Furthermore, specific programs and curricula, such as robotics, can help increase girls' interest in engineering [59]. If students take an engineering class during their high school life stage, they likely had an interest in engineering at the pre-high school stage as well. This shows the importance of engineering at all grade levels.

A few participants explained that their desire to help people informed their decision to study engineering. The desire to help people is a common aspiration engineering students have for their future careers [60]. Women specifically have expressed the desire to help people through engineering [61]. Additionally, a recent study found that high school girls who participated in a STEM camp that included socio-technical instruction had a larger sense of responsibility for the impact that their science can have [62]. Another study identified the career aspirations of URM STEM students and found that the students they interviewed had a strong desire to help others through their careers [63]. Although not true for all students in the sample, two students expressed their desire to help people and considered the socio-technical impacts that engineering can have, which aligns with the literature about women and engineering.

Considering the conceptual model, this work focused on the high school life stage and the high school to college transition. Participants in this study were at the end of their first year, so they had nearly completed the first-year engineering life stage. The first-year engineering experience will inevitably influence students' major choices within engineering. Future work will focus on this choice and part of the conceptual model as it relates to math readiness.

Limitations

This study is limited in a few ways. First, the findings come from a much larger study. The interview protocol was not explicitly developed to understand how women engineering students decide to study engineering when they are pre-math-ready. Additionally, the sample size only includes six participants, so thematic saturation was not achieved. This means there could be more reasons why pre-math-ready women engineering students decide to study engineering. Finally, the interviews capture the students' perspectives at one point in time, after nearly completing their first year of engineering. More insights may be found if the students were interviewed when they applied to college and chose engineering as a major.

Implications and Conclusion

This work aims to better understand how women engineering students who are pre-math-ready decide to study engineering. The first implication is the importance of family members and role models in pursuing engineering. That, combined with the success of mentoring programs, shows the value of having women mentors in engineering to help encourage students to pursue and stay in engineering. Similarly, the prevalence of participation in high school engineering programs was helpful for participants deciding to study engineering, not their math class or achievement. This shows that increased funding and encouragement of women to participate in engineering programs in K-12 will help students decide to pursue engineering. Finally, there was an acknowledgment of the importance of using engineering to help people. If there is a better understanding of the role engineering plays in society, more women may be interested in studying engineering because it will align with their values. Future work will feature longitudinal interviews with pre-math-ready engineering students to understand their experiences in engineering.

Finally, we want to acknowledge that math is important for engineering; however, if we consider students' motivations, we may be able to approach the subject better to encourage more students to study and persist in engineering. For example, if students value their high school engineering classes, college math classes that use engineering applications may be more effective than purely theoretical ones. In particular, the results indicate ways this work can be used to further support women engineering students that go beyond math readiness.

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