Examining Student Success: The Transition from H.S. to College of First-Year Engineering Students

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Abstract

To improve retention and graduation rates, institutions of higher education have become increasingly interested in the experiences of first-year students. This is of even greater importance in STEM (science, technology, engineering and mathematics) fields such as engineering which are crucial for U.S. global competitiveness and homeland security. Interviews were conducted with six (6) first-year engineering students at a large, predominantly White land-grant institution located in the Midwestern region of the country to study their decisions and experiences during the transition from high school to college. More specifically, the investigation focused on under-represented students within undergraduate engineering. Interviews focused on three aspects of college transitions: (a) academic, (b) social, and (c) financial, using Schlossberg's (1995) transition theory and Golrick-Rab's (2007) research as a guide.[1,2] Findings show that prior to college, students enjoyed hobbies such as video games/sports, participated in STEM camps/internships/clubs, and took preparatory STEM courses. Participants tended to choose engineering as an academic major due to parental/family encouragement, interest in previous STEM subjects, and the financial security that engineering jobs provide. Students faced several challenges during their transition to college such as completing application materials, worrying about finances, taking more difficult/time-consuming courses, and feeling overwhelmed.

Introduction

Increasing the enrollment, retention, and graduation of American STEM students has become a national imperative. According to a National Academies report, the U.S. ranks 27th among developed countries in science and engineering (S&E) bachelor degree recipients.[3] As a result, there is a declining number of skilled workers necessary for U.S. jobs in science and technology. This shortage has led to continued job exportation, decreasing U.S. global competitiveness, and a reduction in national security.[4] Indeed, more college-prepared STEM workers are needed for the future job market.

Today, there are approximately 19 million college students across the country, however, historically underrepresented racial minorities (URMs) account for only 32% of the total undergraduate enrollment.[5] Enrollment numbers are even lower for URMs and women in S&E programs. Of all undergraduate engineering students, women account for approximately 18%, Hispanics 10%, Blacks 5%, and Native Americans less than 1%.[6] Based on these data, it's clear that many more women and URMs must be recruited to enroll in STEM fields to meet the nation's goals and future employment projections.

In addition to enrollment concerns, serious measures must be taken to improve retention rates in STEM for such students, especially since approximately 50% of all undergraduates who express initial intentions to major in STEM switch fields during their freshman or sophomore year. Rates of major change are greater for URMs.[7] Low retention rates also tend to lead to low graduation rates. For instance, in science and engineering, 50% of Asian students and 40% of White students complete a bachelor's degree within six years of initial enrollment compared to only 24% of URMs.[7] Due to these alarming numbers, scholars have begun to investigate factors influencing student success in college, especially within STEM. The following section provides a review of related research.

Review of Literature

To conduct this study, it was necessary to review the literature in two areas. First, literature on the transition decisions and experiences of college students was reviewed. Specific attention was given to recent scholarship by Goldrick-Rab.[2] Additionally, previous research on the retention of students in STEM fields was considered, as well as studies on women and URMs in STEM. The literature review is organized around these major themes in the literature.

The Transition to College

Several scholars have directed research attention to the transition experiences of students from high school to college. For example, Terenzini et al.'s work on the transition to college of diverse students suggests that involvement is a key element for student success. The authors stated, "If students become involved in one or another aspect of their new college communities…the likelihood of student change, educational growth, and persistence are significantly increased." [8] In addition, Terenzini et al. lists various ways to ease the transition for college students. Their recommendations ranged from early validation to faculty involvement in orientation, from parental involvement to providing caring and supportive people on campus upon whom students can depend for advice.[8]

More recently, Goldrick-Rab's research on the transition to college reveals that "tracking in high school, academic coursework, and social preparation are particularly strong predictors of both college entry and subsequent performance." [2] Focusing specifically on disadvantaged and minority students, she notes that they "are more likely to receive secondary schooling in vocational rather than academic tracks…take fewer math and science courses…and attend smaller schools lacking precollege preparation programs and counseling." [2] In addition, the author mentions topics involving the transition to college that are not often discussed/researched such as "preparation for college; postsecondary pathways; and college outcomes." [2] When students leave high school to attend college, they encounter various types of transitions including academic, social, and financial transitions.[2] Apart from transition, the literature on students' retention and success in STEM also was reviewed; this is the focus of the next section.

Student Retention and Success in STEM

Past research by Seymour and others has revealed that there are academic and social reasons why undergraduates leave STEM fields.[9,10] Findings from Seymour's study show that students leave

STEM because of (a) lost interest in STEM, (b) perceived greater intrinsic interest in non-STEM disciplines, and (c) rejection of the lifestyle warranted by STEM careers.[9] When focusing on URMs, other researchers proved support from mentors, faculty, peers, and family were also important for retention.[11,12]

Previous studies have been performed to understand the factors influencing student success amongst URMs in STEM. For instance, pre-college preparation has been found to be influential.[13] In addition, having educationally purposeful opportunities to link curriculum to practice, the ability to network, and targeted support systems have been shown to increase student success for URMs in STEM.[14] Not all students experience STEM the same; there can be important demographic differences in students' experiences in STEM.

One demographic difference that has been recognized in the STEM literature is sex or gender. For instance, Vogt et. al identified several factors that increased the success of female students such as "solid academic preparation [i.e. math/science/physics], healthy self-confidence…lack of ambiguity about their choice of major…strong family support and females' high expectations for success." [15] In addition, Marra noted the importance of self-efficacy for women in engineering.[16] Furthermore, Vogt et. al stated that "supportive faculty had a positive relationship with women's development of self-efficacy" and success in engineering.[15]

Extensive research has been conducted to study additional factors that contribute to student success in STEM and even more specifically in engineering. For instance, grit, defined as "perseverance and passion for long-term goals," has been found to be a contributing factor of student success.[17] Furthermore, Duckworth found "academic success and self-discipline were highly correlated … [and] that self-discipline predicted academic performance more robustly than did IQ." [18]

In addition to academic preparation, self-confidence, self-efficacy, supportive faculty, and grit, three-dimensional visualization skills have also been shown to contribute to success within the field of engineering.[19] According to Sorby, "the ability to visualize in three dimensions is a cognitive skill that has been shown to be important for success in engineering and other technological fields." [20] Furthermore, Sorby stated "factors that have been found to be significant for students with well-developed spatial skills include: 1) playing with construction toys as a young child, 2) participating in classes such as shop, drafting, or mechanics as a middle school or secondary student, 3) playing 3-dimensional computer games, 4) participating in some types of sports, and 5) having well-developed mathematical skills." [20] Although we know a good deal about the skills and competencies needed for success in STEM and the transition experiences of students from high school-to-college, we know comparatively little about the transition experiences of women and URMs in STEM fields. This is the gap addressed by the present study.

Purpose

The purpose of the study was to understand the experiences of first-year engineering students during their transition from high school to college. Specific attention was given to URMs, women, and first-generation students while also focusing on the initial challenges they faced in undergraduate engineering programs. The methods are discussed in the following section.

Methods

This qualitative study relied upon interviews with first year engineering students. Freshman engineering students were studied because of their unfamiliarity with extensive engineering coursework and recent experiences in primary/secondary school. Therefore, it was expected that they could easily remember how they entered and transitioned into college.

Sample. To understand the transition experiences of first-year engineering students from underrepresented groups, "information rich" participants were selected using a purposeful sampling approach. Specifically, all participants shared several important characteristics. First, only first-year undergraduates were recruited as participants to eliminate any unforeseen variability in experiences between more experienced undergraduate and graduate students. Second, all participants had declared an anticipated major in engineering or a related subfield of engineering (e.g., mechanical), as defined by the National Science Foundation (NSF).

The study took place at a large mid-western university with an eligible population of nearly 1,600 first-year engineering students. Of those 1600 students, nearly 22% self-reported as being a female, over 15% claimed to be first generation college students, and almost 7% identified as an underrepresented ethnic minority (i.e. African-Americans, Hispanics, and Native Americans), according to the institutional research unit on campus.

Participants were recruited using a variety of strategies including electronic announcements about the study to several hundred of the eligible students using college listservs. Student participation was voluntary; no monetary compensation or incentives were offered. Willing participants were contacted via email by the researcher to confirm their participation, review informed consent information, and schedule a day and time for the interview.

This approach yielded 6 interview participants (3 males and 3 females). Demographic data were self-reported by participants. Table 1 and Table 2 present this information. The following pseudonyms were given to each participant: Walter, Andrew, Ashley, Whitney, Blake, and Heather.

Table 1: Description of Sample (N=6)

Variables	**%**
Academic	
College classification	
Freshman, first-year	100
Enrollment status	
Full-time	100
Pre-Major	

Engineering Undecided	33.3
Biomedical Engineering	16.7
Computer Science & Engineering	16.7
Industrial Systems Engineering	16.7
Mechanical Engineering	16.7
Demographic	
Sex of student	
Male	50.0
Female	50.0
Ethnicity	
Caucasian/White	33.3
Hispanic	16.7
Multi-racial	50.0
w/ African-American	16.7
w/ Asian/Pacific Islander	33.3
First-generation	
Yes	50.0
No	50.0

Table 2: Detailed Demographics of Individual Research Participants

	Walter	**Andrew**	**Ashley**
Gender	Male	Male	Female
Ethnicity	Caucasian	Multi (Pacific Islander, Caucasian)	Asian-Amer. (Japanese, Caucasian)
Pre-Major	Eng. Undecided	CSE	BME (switching to CSE/ECE)
1st-Gen.	No	Yes	Yes
	Whitney	**Blake**	**Heather**
Gender	Female	Male	Female
Ethnicity	Caucasian	Multi (Afr.-Amer., Native Amer., White)	Hispanic
Pre-Major	ISE	ME	Eng. Undecided
1st-Gen.	No	Yes	No

Data Collection and Analysis. One-on-one semi-structured interviews were conducted with each of the 6 participants. Interviews were conducted in a private office, located on campus, by the researcher. Each interview lasted between 30 to 40 minutes. An audio recording device was used during the interviews. Following the interviews, each recording was transcribed and topically indexed.

Limitations

Before results from this study are discussed, several limitations should be considered. First, data was drawn from a relatively small sample of participants at a single institution. Therefore, results from the current sample may have limited generalizability. Nonetheless, these findings offer motivation and direction for future work with a larger student population. Additionally, qualitative studies rarely aim for generalizability (i.e., breadth). Instead, the explicit purpose of such studies is to share deep insight about the experiences of fewer subjects (i.e., depth).[21, 22] Findings should be interpreted with this in mind.

Secondly, the study was informed by previous research on transition to college. Grounding the study in this literature allowed the researcher to pay attention to some aspects of the transition experience (e.g., financial, academic, social), but it may also inadvertently blind the researchers to other areas that are unaddressed by transition theory. This is a limitation of all theory-based studies. Findings may be influenced by the choice of theory.

Although important, these limitations do not reduce the study's usefulness in understanding the experiences of first-year engineering students as they transitioned from high school to college. Particularly, the when focusing on the experiences of URMs, women, and first-generation students.

Findings

The interview protocol elicited information on students' previous school environments, pre-college STEM courses (i.e. in math, science, and technology), work experience, involvement in extra-curricular activities, and childhood hobbies. Major themes were identified from the collective student responses. When summarizing student experiences prior to college, the following themes emerged: nearly half of students (a) enjoyed hobbies such as video games/sports, (b) participated in STEM camps/internships/clubs, and (c) took preparatory STEM courses (e.g. algebra, geometry, calculus, statistics, physics, chemistry, computer science, drafting, etc.). Interview data showed that students chose engineering for the following reasons: (a) interests and achievement in STEM subjects, (b) parental/family encouragement, and (c) financial/job security. When transitioning to college, more than a third of students also faced challenges such as: (a) completing application materials, (b) worrying about finances, (c) taking more difficult/time-consuming courses, and (d) feeling overwhelmed. For instance, all but one participant described challenges with coursework. For example, Blake talked about difficulties adjusting to college classes when saying:

> There was a drastic change in like the amount of coursework and the type, like the class styles, when I first got [to college].

Below are additional descriptions of the themes that were identified in this analysis. Each theme is supported by direct quotes from the interviewees that provide clarity, insight, and reveal unique student experiences during the transition from high school to college.

Pre-College Experiences

Table 3: Summary of Pre-College Experiences

	Number of participants	Percentage of participants
Played sports	6	100%
Took calculus prior to college	6	100%
Played video games	5	83%
Took physics prior to college	5	83%
Took chemistry prior to college	4	67%
Participated in STEM camps/internships/clubs	2	33%

As shown in Table 3, findings from the interviews revealed that prior to college nearly all students enjoyed playing sports and video games. Engagement in sports and games seemed to nurture their early interest in STEM. For instance, Walter shared:

> I played a lot of sports in high school, like my freshman and sophomore year I played football and freshman through senior year I played baseball and varsity baseball.

Like Walter, Whitney also described her experience playing sports when saying,

> I played basketball and tennis pretty much my entire life.

In addition to sports, students also mentioned their experiences and interest in video games. When discussing his curiosity in video games, Andrew displayed an interest in not only playing them but also learning how they work.

> I have been looking into…the design of video games and figuring out why things work and why they don't and what makes it fun versus why did this game get a really high score.

Blake described translating his love for video games into career aspirations through the following quote:

> I really like to design cars. Like I would play video games where you design cars and race them and what not. And I realized that's what I want to do for the rest of my life.

In addition to playing sports/video games, several students also participated in STEM organizations such as summer camps, internships, and school clubs.

Ashley described her time at an internship prior to college through the following statement:

> I spent…two summers consecutively…in UC's Physics department and helped them with part of the physics research which is a lot bit more heavy duty stuff. So, it like introduced me to like research. It introduced me to more on the science side.

Moreover, Andrew spoke of his experience at a space camp and the lasting impression it had on him.

> [My parents] sent me to space camp…the U.S. Space and Rockets Center…you can just spend the whole week learning about sciences and stuff and I absolutely loved it. I actually have a picture of me being 11 in front of a sign that says "through these doors enters America's future astronauts, scientists, and engineers.

Furthermore, prior to college the majority of students took preparatory STEM courses. All students reported taking calculus, all but one took physics, and all but two said they took chemistry. Walter spoke of his early exposure to math but desire to take more physics courses.

> I took algebra in 7th grade and geometry in 8th grade and so on. And, then yeah I took Calculus my junior year [of high school] and AP stats my senior year…College physics is definitely a lot harder than in high school which is why…I should've taken AP Physics my senior year, but instead I took regular physics.

Similarly, Andrew talks about the impact that taking high school calculus and computer science had on his academic experiences and decision to choose engineering in college.

> AP Calculus…that really I think set me up well for most of the classes that I've been taking [in college]…I had a feeling that I wanted to go into programing ever since I took AP Computer Science my sophomore year…I had chosen engineering over computer information science, mostly because I wanted to get into the more technical aspect of engineering and computer science.

Ashley mentioned how much she enjoyed taking physics and calculus in high school through the following words:

> AP Physics definitely helped and I remember Calculus definitely helped um 'cause I would take those classes and be like this is actually kind of cool, I've never learned this before.

Blake referred to the link between his preparatory science courses and path into engineering.

> After taking chemistry…I had taken Physics A and then Honors Physics B. I felt like those really…helped me into the process of becoming an engineer.

The above quotes provide insight into the pre-college experiences of first-year engineering students in terms of their hobbies, involvement, and academic preparation for college. The next section will summarize the reasons why participants chose to major in engineering.

Reasons for Choosing Engineering

Table 4: Summary of Participants' Reasons for Choosing Engineering

	Number of participants	Percentage of participants
Liked math	5	83%
Encouraged by parents/family	4	67%
Liked science	3	50%
Liked technology	2	33%
Expected income/job security	2	33%

As displayed in Table 4, during the one-on-one interviews, each participant revealed reasons for choosing engineering as an anticipated college major. Study findings revealed that all 6 participants mentioned having an interest in either math, science, or technology before choosing engineering as a major. Walter, offered the following statement:

> Throughout high school like math was definitely my strong point … [engineering] is a major that has to do with math.

Similar to Walter, other students also mentioned liking math, science, or technology prior to college. For example, Ashley said the following:

> I realized that I was really going to miss all of my [high school] math and science classes.

In addition, Andrew noted,

> I've always thought engineers were some of the coolest professions just because you are the ones that create advancements, you create technology, you push…the world forward. And I guess I've always wanted to be a part of that, being a part of creating something new.

Furthermore, Blake stated:

> I'm really interested in technology and I'm very good in math. And…advisors [in a college preparatory program]…told me that I should look into a field of engineering.

The statements made by Walter, Ashley, and Blake show a clear link between interests or achievement in pre-college STEM-related coursework and the decision to major in engineering. In addition, students also mentioned parental/familial encouragement when choosing engineering. Walter offered the following description:

> My parents told me 'hey' like this is a major that has to do with math … [also] my stepdad was an engineer…I think he was [in] industrial and systems engineering… he became like really successful really fast and yeah after I heard that like I definitely wanted to become an engineer.

Whitney added:

> My mom just told me 'You should be an engineer…you know you're good in math and science and they do a lot with that.'

In addition, Heather talked about having family members in engineering who were role models.

> Um, well I have two aunts that have both been engineering majors…so that was kind of a no brainer for me to follow that since I was more oriented towards science and math in high school.

Based on Walter, Whitney, and Heather's accounts, receiving words of advice from parents and having family members serve as role models influenced their decision to pursue engineering.

Another theme that emerged from the interviews was income level and job security. Below is a supporting quote from Walter:

> You get a lot of money for it [being an engineer].

Similarly, Heather offered the following illustration:

> [Engineering] it was a really safe major to go into. You could come out making 50 grand [$50,000] and make a good living and you could still only have your undergrad…you can go out and find a job.

The above excerpts reveal several reasons why students chose engineering as an anticipated major. The next subsection contains information about challenges they faced while transitioning into college.

Challenges Faced while Transitioning

Table 5: Summary of Challenges Faced by Participants while Transitioning to College

	Number of participants	Percentage of participants
Difficult/time consuming courses	5	83%
Felt overwhelmed by college	3	50%
Application process	2	33%
Financial worries	2	33%

As seen in Table 5, interview participants experienced various challenges when transitioning from high school to college. All but one participant reported having to take <u>difficult/time consuming courses</u> after arriving to college. Similar to the earlier quote from Blake, Walter expressed his thoughts on college coursework through the following statement:

> College physics is definitely a lot harder than in high school…First quarter I took Chem. [Chemistry]…and like that was really hard to get used to because of all the work you had to do.

Whitney also revealed challenges with coursework.

> Fall Quarter of engineering was hard, it was definitely a struggle for me… the drawings and the labs and…the breadboards and the circuitry was really hard. I've never worked with stuff like that...Math…is hard because I do not have the best professor this year so I'm basically teaching myself a lot of everything.

A second theme that participants mentioned was <u>feeling overwhelmed</u> by college. For instance, Ashley said:

> When I first came here…I don't want to say it was overwhelming but it kind of was. I remember there were so many different…things to do here like so many ways to just get involved, so many classes I can take…and, then I wasn't completely sure on what kind of engineering I wanted to do or what kind of job I wanted to get.

Furthermore, Whitney mentioned:

> Um, move in day was a little overwhelming to see everyone coming in and you're supposed to fit 4 people into this 1 room are you kidding me.

Lastly, Blake states:

> I was very overwhelmed because there was…so much to do…so many opportunities … [also] I felt overwhelmed all the time just because…honestly I had developed um a vivid social life before I had like gotten down into my studies. So, I felt like that might have hurt me a little bit because I was spending a lot more time socializing than I would actually be studying.

Another theme that emerged besides having difficult/time consuming courses and feeling overwhelmed was <u>difficulty completing the application process</u>. For example, Walter said the following:

> It was just kind of a challenge like going through the entire application process myself like not having my parents help me.

Blake had a similar experience with the application process. He stated:

> When it came to applying, um it was very, it was actually a very difficult process because uh I was sort of lazy my senior year.

In addition, to difficulties completing the application process, students also <u>worried about finances</u> when transitioning to college. Andrew mentioned:

> I'm mostly on loans, which sucks… it's kind of like a burden at like the back of my mind.

Furthermore, Heather said:

> I've taken out student loans so I mean I've just got to worry about that.

In summary, students tended to choose engineering as a major due to parental/family encouragement, academic achievement in previous math/science courses, an interest in areas such as technology, and the salary/security of an engineering job. When transitioning to college, students faced challenges such as completing application material, worrying about finances, taking more difficult/time-consuming courses, and feeling overwhelmed by the many opportunities available to them. The next section will discuss the findings, state conclusions, and offer future implications.

Discussion

Findings from this study suggest several important conclusions for the transition and academic success of first-year students in engineering. First, results from the present study indicate that underrepresented first-year college students' interest in engineering was nurtured by specific activities such as playing sports, video games, and early exposure to science and math courses. Participants shared how involvement in such activities influenced their skills and abilities in areas that were important for succeeding in engineering. Such findings lend support to earlier work by Crisp et al. on the significance of pre-college preparation for URMs.[13] It also extends the list of activities identified in Sorby's previous research that were said to increase students' 3-D visualization skills and chances for success in engineering.[19,20]

Secondly, results show that, at an early age, underrepresented first-year engineering students had educationally purposeful opportunities to link curriculum to practice and network through involvement in STEM camps, internships, and school clubs. Participants revealed how participation in such activities further developed their skills and influenced their decision to enter engineering. These results add to previous findings from Museus and Liverman about the need to provide URM students with targeted support systems and opportunities to apply curriculum in real-world contexts.[14]

Lastly, findings from the present study show that students tend to choose engineering as a major if encouraged and supported by family, recognized for their abilities in math and science, and made aware of the profession's growing demand and monetary rewards. Students' transition into college could be eased through help completing application material, more financial support, assistance with initial academic coursework, and advice on ways to manage the range of available academic and social opportunities in college. These results are in agreement with Vogt et al's previous research focusing on female students' preparation, support, and ultimate success in STEM.[15]

Conclusion

While seeking to determine what makes students successful when majoring in engineering disciplines, it was important to examine their transition into to college.

In future research, follow-up interviews might be used. The purpose of the follow-up interviews could be to gain student's perspective over time. It may also be helpful to study older undergraduate engineering students, graduate students and engineering faculty members at similar institutions. More experienced engineering students and faculty will have additional insight into the role that college/the workforce played in helping them succeed in engineering. Furthermore, a quantitative analysis (e.g. survey) could be performed and compared to the current qualitative results.

Due to an increase in global competition, the need for more skilled workers in STEM disciplines, and the necessity of a college degree in today's job market it is important to retain and admit a diverse pool of engineering students.[23,24,25] Therefore, results from this survey can be used for STEM initiatives and enhancements targeting underrepresented student groups. In addition, this data can be used to develop a model for effectively helping underrepresented student groups transition into a first-year engineering program.

Results from the study indicate that there are implications for engineering education faculty, professors in engineering disciplines, and even parents or guardians of students who aspire to pursue engineering professions.

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