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Examining the Personal Nature of the K-14 Engineering Pipeline for Young Women

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Abstract

This mixed-methods research study examined young women's perceptions of their K-14 STEM pipeline experiences and their resulting choice to enter and persist in an engineering major. Despite the increasing presence of women in the STEM workforce, they remain underrepresented among engineering majors (Beasley & Fischer, 2012; Heilbronner, 2012; Neihart & Teo, 2013). Outside of the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) survey, few studies exist that utilize a retrospective approach to understanding how young women's K-14 experiences have influenced their formation of individually held perceptions leading to engineering persistence. This study utilized a mixed-methods approach to obtain quantitative data on the sample population's prior and current academic data, as well as demographic data. Following the quantitative survey, qualitative methods were utilized to gain a better understanding of how these educational experiences and demographics had influenced the young women's decisions to enter and remain in the engineering program of study. The following research question was addressed: How do young women's perceptions of their K-14 STEM experiences influence their decision to enroll and persist in an engineering major? These perceptions were explored through an ethnographic approach focusing on young women in their junior and senior years in an engineering program at a small private liberal arts university. Survey and focus group responses were then analyzed in connection with the young women's successful enrollment and persistence in engineering programs at the research site. The mixed-methods approach followed a sequential design (Creswell, 2013) and utilized questions in a quantitative Likert-type survey from the Academic Pathways for People Learning Engineering (APPLES) survey (Eris, Chachra, Chen, Sheppard, & Ludlow, 2010) and the Motivated Strategy Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991). The quantitative study results, which were analyzed using Statistical Package for the Social Sciences (SPSS), led to the development of open-ended, structured questions for two qualitative focus groups that were conducted in March 2016. Qualitative data were analyzed using line-by-line hand-coding and NVivo software. Anonymity of all participants wasmaintained.

Introduction

In 2005, a congressional report addressed growing concern over the United States' diminished global standing in mathematics, science, and innovation (National Academies of Science, Engineering, & Medicine [NASEM], 2005). *Rising Above the Gathering Storm* prompted a nationwide effort to implement the committee's recommendations for improving science literacy across K-16 educational settings. In response, the National Science Foundation (NSF) began developing Next Generation Science Standards and cultivating a nationwide effort for 21st-century science literacy. By 2010, the American Association of University Women (AAUW) had also released a report outlining gender inequalities in engineering-degree completion and underrepresentation in STEM careers (Corbett, Hill, & St. Rose, 2010). This report resulted in focused efforts to develop science literacy in public schools and to provide funding for equal access to STEM opportunities in public schools.

Five years later, the follow-up congressional report, *Rising Above the Gathering Storm Revisited* (2010), showed more sobering statistics. United States students ranked 15th out of 65 countries/regions in science literacy, while top students ranked 28th for mathematics literacy. Additionally, 15-year-olds' mathematics proficiency was estimated to be about 50%, with the United States ranking 31st out of 65. These data translate to the United States ranking 27th overall in the proportion of college students receiving science and engineering degrees (*Rising Above…Revisited*, 2010).

Furthermore, K-14 educational programs that do support the STEM pipeline are small in scale (Ralston, Hieb, & Rivoli, 2013), leaving 78% of high-school graduates unable to meet college readiness requirements in entry-level mathematics and science courses (*Rising Above…Revisited*, 2010). These statistics led the congressional committee to recommend increasing federally funded research in mathematics, science, and engineering and encouraging United States citizens to work in these fields. Since we rely on public schools to provide high-school graduates prepared to enter these careers and task our universities with preparing tomorrow's innovative workforce, it is critical to examine our students' perceptions of their own skill development, feelings of self- efficacy, and formation of STEM identities throughout the STEM pipeline.

Underrepresentation of Women in Engineering

As an underrepresented group in the STEM fields, young women's standards for mathematics achievement are lower than young men's, resulting in lower self-efficacy and greater feelings of self-doubt that negatively contribute to a woman's decision to enter the engineering field (Heilbronner, 2012). Bandura (1997) defines self-efficacy as an individual's belief in his or her capacity to perform at a desired level and the effect of his or her own control and confidence to achieve that level. This belief about one's own capabilities can strongly influence academic persistence, as is evident in data from one longitudinal study that evaluated female engineering students' perceptions of inclusion in their college engineering environment. Participants were assessed using the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) survey, which has a Cronbach's alpha reliability coefficient ranging from 0.72 to 0.87, ultimately demonstrating that overall, female engineering students felt they were not included in their college engineering environment (Corbett et al., 2010).

AAUW's report *Why So Few?* (2010) indicates that despite young women's recent gains in STEM areas like biology and the biomedical fields, they continue to be underrepresented in technology and engineering fields. Factors influencing this trend include gender bias, low self-perception of mathematical ability, and the presence of stereotype threat, which occurs when individuals feel at risk for underperforming based on their social group's expectations. Lower retention rates of first-year college engineering majors (Corbett et al., 2010; Steele, 1997; Steele & Aaronson, 1995; Steele, James, & Barnett, 2007) reinforce the need for further research examining young women's perceptions as they navigate the STEM pipeline experiences constructed in American schools to advance engineering and innovation for underrepresented groups.

Though the 2014 ASEE annual survey revealed a 6% growth rate in engineering-related bachelor's degrees awarded across all genders, women comprised only 20% of degrees awarded in the STEM fields, up from 18% in 2013. A closer examination of the data reveals a significant difference in specific bachelor's degrees awarded to women, with the highest percentage being awarded in environmental, biomedical, biological, and agricultural engineering disciplines, and the lowest in computer, mining, and mechanical engineering disciplines. An even starker difference appears when the data is broken down by minority representation of women in engineering degrees. In 2014, engineering degrees awarded to women were highest for Whites and Asian Americans and lowest for Hawaiian/Pacific Islanders, American Indians, and Black or African American women.

Based on data compiled in the survey, women are underrepresented as both an ethnographic group and a gender. This shortage is cause for alarm and should motivate us to research women's experiences, self-efficacy, and individual perceptions leading to persistence in engineering fields.

Purpose and Significance of the Problem

The purpose of the present study was to examine young women's retrospective perceptions of their experiences in the K-14 STEM pipeline, as well as the influence of specific interventions on their pursuit of and persistence in an engineering major at a university. Despite current research that identifies best practices for STEM interventions that support the formation of young women's STEM identity (AAUW, 2010), a persistent research gap exists on how women's experiences affect their decision to enter and persist in engineering. Increased knowledge about women's K-14 experiences, including the supports that may have influenced persistence, will provide additional insight into how to construct an environment that encourages young women to enter and persist in engineering majors.

This mixed-methods sequential study utilized a survey and a focus group to provide insight into female students' feelings of self-efficacy and perceptions of the academic, social, and personal experiences that led to their enrollment and persistence in a post- secondary engineering program. These research findings will help enable K-14 educators to make informed decisions about deliberate efforts to engage and support young women, both in their career through pre-engineering and engineering curriculum supports and in the transition from high school to college.

Research Question

The following research question was explored in this study: How do young women's perceptions of their K-14 STEM experiences influence their decision to enroll and persist in an engineering major? The sequential approach allowed the researcher to construct specific focus group and interview questions based on an initial quantitative survey to gain an in-depth understanding of young women's unique perceptions of K-14 STEM interventions. The questions addressed the experiences, perceptions, and feelings of self- efficacy behind students' successful navigation of the engineering pipeline.

Definition of Terms

The following key terms are utilized throughout this research: *STEM* (Science, Technology, Engineering, and Mathematics) and *STEM identity*, which is the formation of one's personal connection to the STEM majors and studies (Carlone & Johnson, 2007; Hughes et al., 2013) as it relates to each young woman's current reality. For the purposes of this study, the term *pre-engineering pipeline* represents students' K-14 STEM and engineering experiences. *Self-efficacy* refers to one's feelings of adequacy in one's ability (Bandura, 1997) and self-perception of achievement. Additionally, *underrepresentation* means the limited presence of women as a subgroup in the engineering field. The term *engineering* is meant to encompass the eight engineering majors of academic study at the institution being researched, including biomedical, chemical, civil, computer, computer science, electrical, environmental, and mechanical engineering.

Review of the Literature

The following three areas of research have emerged surrounding young women's entrance and persistence in STEM majors, specifically engineering: 1) Self-efficacy, the social cognitive theory, and the formation of a STEM identity; 2) pre-engineering pipeline experiences; and 3) gender equity and the underrepresentation of women in engineering.

Generally, the social cognitive theory is applied to educational practices to describe students learning by observing others when desirable behavior is modeled (Bandura, 1997). This theory provides insight into one's formation of self-efficacy, which Bandura (1997) defines as "beliefs in one's capabilities to organize and execute the course of action required to produce given attainments" (p. 3). Self-efficacy is the primary basis for the social cognitive theory because it affects students' feelings of ability related to interactions in behaviors and personal beliefs in their learning environment. Social cognitive theory is integral to the belief and acceptance that one's intellectual abilities are not predetermined but are constantly being formed by new experiences and learning opportunities; these abilities can be improved over time and are influenced by the connection students make with the learning experience (Kolb & Kolb, 2005). Both environmental and individual factors affect young women's connection to learning in the classroom, including differences in learning styles and the ability to connect relevance to the material being taught (Kulturel-konak et al., 2014).

Several factors contribute to the problem of retention in engineering, including cognitive factors such as GPA and SAT math scores; non-cognitive factors like interactions with peers and professors; individual characteristics like family educational background, gender, and ethnicity; institutional characteristics like environment, type, and size; and the relationship between individuals' feelings of self-efficacy and their skills and personal attributes (French et al., 2005; Tinto, 2006). Despite models for retention and an increased focus on engagement during the freshman year, however, many universities are not making significant changes in student retention rates (Tinto, 2006).

A qualitative study involving the California-based Mathematics, Engineering, and Science Achievement (MESA) program was conducted on underrepresented student populations (Densen et al., 2015). Given the success of the MESA program as an informal experience that is effective in recruiting and retaining underrepresented students in STEM careers, this grounded theory approach utilized focus group interviews with five groups of students who participated in the program. This program is co-curricular and supports disadvantaged students by providing opportunities for minority students to be successful in STEM disciplines. The following eight themes emerged in the findings as influential to student success: 1) Informal mentoring, 2) makes learning fun, 3) time management, 4) application of math and science, 5) feelings of accomplishment, 6) builds confidence, 7) camaraderie, and 8) exposure to new opportunities. The study's findings imply that these themes should be incorporated into both formal and informal learning environments to teach and reform the way STEM content is taught.

In addition to disadvantaged and minority students, research exists to support a nurturing environment for young women in engineering. Specifically, a more supportive environment and reinforcement for women is needed to increase their representation within STEM degrees and careers (AAUW, 2010; Kerr & Robinson Kurpius, 2004; *Rising Above…Revisited*, 2010). Women continue to be underrepresented in engineering majors and require additional interventions to improve these outcomes (AAUW, 2010).

The literature also notes best practices in developing young women's self-efficacy and providing opportunities for their social learning support (Bandura, 1997; Halpern et al., 2007; Heilbronner, 2009). Standard methods of instruction in the science and mathematics classroom should be included to further diminish the formation of stereotypes and improve girls' self-perception of math and science ability and skill acquisition (Halpern et al., 2007). One mixed-methods study involving over 70,000 students at eight higher-education institutions compared students entering and remaining in an engineering major. Findings showed that industrial engineering was the only engineering major that continued to experience growth among female students (Brawner et al., 2012). Data collected through student interviews revealed that retention most commonly occurred in nurturing environments, described as providing warmth, supportive staff members, and a valuable social network. Thus, the environment embedded in departmental culture and the degree program play a significant role in recruiting and retaining women in engineering majors and in women's STEM identity development (Brawner et al., 2012).

However, gaps remain in research on the potential relationship between interventions to encourage young women's selection of a STEM major in college and their long-term decision to pursue STEM careers in male-dominated fields. The existence of a social- psychological threat is referred to as stereotype threat, where a decrease in overall performance occurs when an individual perceives the presence of a negative stereotype (Spencer et al., 1999; Steele, 1997; Steele & Aaronson, 1995). In academic settings, such as testing situations, young women and minorities perform at lower levels when they are aware they are being compared to their White male counterparts (Spencer et al., 1999). In the field of engineering and STEM majors, dropout has been attributed to stereotype threat for women and minorities (Steele et al., 2002).

Research Site and Population

According to the Institutional Research Fact Book (2015) for the research site where this study was conducted, the university has 702 degree-seeking undergraduate engineering students. The College of Engineering contains six engineering departments and eight majors, including biomedical, chemical, civil, environmental, computer, computer science, electrical, and mechanical engineering. Thirty-two percent (225) of the engineering students across all six departments are women.

Information on the population involved in the research study was obtained from the research site's Office of Institutional Research (OIR). The study group consisted of 112 full-time undergraduate female students, ages 19-21, in their junior or senior year at the research site. To participate in the study, the students could be enrolled in any engineering major; the study sample was purposefully selected as a representative ethnographic group across all engineering majors. A purposeful sampling method was also employed for the focus groups to ensure participants represented the ethnic breakdown of the larger group of young women enrolled in engineering programs at the research site. Students may or may not have utilized university supports, including intervention programs designed to assist struggling students with skills development.

Quantitative Research Methods

The first part of this mixed-methods study (Creswell, 2013) involved disseminating a quantitative survey to all female junior and senior students (n=112) enrolled across all engineering majors at the research site. The researcher designed a new 38-question survey (Combined APPLES and MSLQ Perceptions and Motivations for Persistence in Engineering Survey) by combining demographic questions, questions from the MSLQ developed by Paul Pintrich and others (1991), and questions from the APPLES instrument developed by Eris et al. (2010) and adapted from the Persistence in Engineering (PIE) survey instrument to explore the engineering student experience. The PIE survey was originally developed to identify factors correlated with persistence in engineering as part of the CAEE's (2007) Academic Pathways Study (APS), which identified 21 variables for persistence in engineering. The instrument's overall goal was to collect data utilizing relevant questions from each survey instrument on individuals' experiences and perceptions during their K-14 and academic careers and to create a comprehensive picture of the culture-sharing group – in this case, the young women that had persisted in the research site's College of Engineering.

The MSLQ questions were used to identify within the results a measure of motivational orientation for college engineering students (Pintrich et al., 1991) and examine women's feelings of self-efficacy to determine if patterns existed among the women in the engineering program. Taking Pintrich et al.'s (1991) approach, the survey incorporates the concept of engineering into the MSLQ by replacing the term "class" with "engineering classes." A self-efficacy score was recorded. A Cronbach's alpha score of 0.70 was determined for the internal consistency of the responses, and descriptive statistics were utilized for all demographic variables. Seven engineering experiences were found to be statistically significant in impacting students' self-efficacy relative to their peers who did not have any pre-engineering experiences. Additional questions were taken from the APPLES survey to determine if a similar pattern of variables existed in key issues related to engineering education. These questions examined the student engineering experience, demographics, motivations to study engineering, and the importance of skills developed from first-year to senior-year students (Eris et al., 2010). Both the MSLQ and APPLES instruments have been tested for reliability, but this is the first time a combined survey instrument utilized questions from both instruments. This pilot enabled the researcher to determine if the subjects understood the questions, establish the time needed to take the survey, and decide if any questions needed to be modified for clarification. Ten engineering students in either their freshman or sophomore years were asked to complete the survey. Due to the small sample size and the need to exclude the subjects who took the pilot test, no junior or senior women were utilized. All instrument modifications were made following the pilot study conducted from January to February 2016.

The research site's Dean of Engineering distributed the instrument online to all possible female junior and senior engineering students, approximately 75. As an incentive to participate, students who completed the survey were entered into a drawing for an Amazon gift card. The instrument was expected to yield a 33% response rate (n= 37) (Nulty, 2008), which is consistent with online response rates for surveys of college students. The survey was designed to eliminate any duplicate responses, and the Statistical Package for the Social Sciences (SPSS) tool embedded in Microsoft Excel was utilized to analyze the data and report descriptive statistical measures from the completed survey. Descriptive statistics, including measures of central tendency, were utilized in data interpretation.

Sample Demographics

The following figures indicate the demographics of the engineering students enrolled at the research site, where N=702 with 32% of the students identifying as female (n=224). This enrollment is similar to gender enrollment reported by Yoder (2015), where females comprised 20% of the total population of engineering students for Fall 2014 bachelor's degree enrollment at universities in the United States, including Puerto Rico.

Table 1 shows the total number of female engineering students enrolled at the research site by race for the Fall 2015 semester. This data was obtained from the research site's OIR prior to the survey distribution. The highest percentage of females in engineering at the research site university is classified as White (72%), followed by Asian/Asian American or Multiple Races (4% each). Black or African American females comprise only 3% of the population, and the smallest percentage of female engineers (1.5%) is represented by unknown ethnicities. These data are consistent with national data, which indicated in 2014 that female-awarded engineering degrees were granted most often to White (55%) and Asian American women (14%) and least often to Hawaiian/Pacific Islander women.

Table 1
Race/Ethnicity of Institution

Institutional Category	***n***	***%***
Asian or Asian American	9	4
Black or African American	7	3
Hispanic or Latino/a	12	5.5
Multiple Races	9	4
Non-Resident Alien	22	10
Unknown	3	1.5

The number of faculty and engineering students are included to demonstrate the faculty-to- student ratio and the small size of the research site. Thirty-two percent of all engineering students (N=702) across all academic-year standings, including 5th-year program students, identified as female. The faculty-to-student ratio, 1:10, was determined based on the total number of students and full-time faculty. The institution's 2014-15 graduation rate was 90% for women who had entered as freshman in the engineering program and were awarded engineering degrees as graduates of the College of Engineering. This data is significant with respect to the sample being identified as a representative ethnographic sample for persistence in engineering, as shown in Table 2.

Table 2
University Engineering Students & Faculty Data (2015-16 SY, 2014-15 Cohort)

Indicator	***n***
# Total engineering students (male & female)	702
# Women (all years) engineering students	224
# Women with junior-year standing	46
# Women in the 5-year degree program	5
# Women with senior-year standing	60
# Full-time engineering faculty	72
Student-to-faculty ratio	1:10
% Women for the representative population sample	16
% Women in engineering	32
% Women entering and graduating as engineers	90

Descriptive Statistics

A total of 61 women responded to the survey, for a 40% response rate. The population studied was a purposeful sampling of junior and senior women at the research site's College of Engineering. They were representative of a larger ethnographic group of female students that have successfully persisted in engineering at the university.

Demographic factors, including socioeconomic status of the sample studied, are shown in Table 3. In the survey, this status was self-selected by the respondents (n=40) and was based on the federal income guidelines utilized by the research site's OIR. When given the ordinal scale selections of high income (5), upper-middle income (4), middle income (3), lower-middle income (2), and low income (1), 52.5% (n=19) of the students identified their families as high or upper-middle income. Only 15% (n=6) of the survey respondents identified as lower-middle or low-income earners. Notably, most respondents classified themselves and their families as upper-middle income (n=16, 40%) and middle income (n=13, 32.5%), representing 72.5% of all respondents. The least-reported category was low income (n=2), which comprised only 5% of

Table 3
Socioeconomic Status of Study Sample

Income Status	***n***	***%***
Low income	2	5
Lower-middle income	4	10
Middle income	13	32.5
Upper-middle income	16	40
High income	5	12.5

the respondents.

The researcher collected additional participant demographic data to include racial identification, as aligned with the OIR's category descriptions. Table 4 represents the raw data for each race category and gender, as identified by respondents. Students were permitted to identify with more than one group; thus, the total number of responses is greater than the total number of survey respondents.

Table 4
Racial / Ethnic Identification

Racial/Ethnic Category	**%**	***n***
American Indian or Alaska Native	0	0
Asian or Asian American	10	4
Black or African American	5	2
Hispanic or Latino/a	5	2
Native Hawaiian or Pacific Islander	3	1
White	90	36
Other	0	0

Demographics for the study indicated that Whites (90% of the study population) and Asian/Asian Americans (10%) were the most-represented categories in the sample population, while American Indian/Alaska Native (0%) and Native Hawaiian/Pacific Islander (3%) were the least- represented categories.

Levels of parental education were also examined since current research literature indicates that several factors, including family educational background and environment type (French et al., 2005; Tinto, 2006), contribute to lower student retention in engineering. Table 5 identifies education levels among respondents' mothers and fathers. Most respondents' fathers (81%) and mothers (77.5%) had completed either a bachelor's degree or a master's degree. Only a small representation of the sample (5% of the participants) listed high-school graduation as their mothers' highest education level, while only 8% reported the same for their fathers. No participants identified

Table 5
Parental Level of Education

Mother	***N***	**%**
Did not finish high school	0	0
Graduated from high school	2	5
Attended college but did not complete degree	0	0
Completed an associate's degree	5	13
Completed a bachelor degree	20	50
Completed a master's degree	11	28
Don't know or not applicable	2	5
Father		
Did not finish high school	0	0
Graduated from high school	3	8
Attended college but did not complete degree	0	0
Completed an associate's degree	1	3
Completed a bachelor's degree	19	48
Completed a master's degree	13	33
Don't know or not applicable	4	10

either their mothers or fathers as having dropped out of high school or a higher-education program. This data suggests there may be a relationship between young women's degree pursuit and parental degree persistence and completion.

Research also indicates that academic factors contribute to retention in majors such as engineering. To examine the academic indicators of female students who had persisted in the engineering field, quantitative survey questions addressed the participants' current major GPA to demonstrate academic achievement within the research site's engineering program (French et al., 2005; Tinto, 2006). Thirty-nine percent of respondents' GPAs fell into the upper range of 3. Most survey respondents reported higher GPAs that fell in the range of 3.5 – 4.0. Participants' perceptions of their ability to meet the engineering major's demands are also included in Figure 3 to determine if data supported feelings of self-efficacy aligned with academic performance, as measured by GPA within the major. Findings for the sample indicate that 100% of the subjects felt they could meet the demands and hard work required of their major, consistent with higher GPA values.

Research also indicates that formal pre-engineering experiences can include an Advanced Placement (AP) curriculum to advance students in engineering and prepare them for the rigors of a college-level engineering major (French et al., 2005; Ralston et al., 2013; Tinto, 2006). Subjects were surveyed on their formal pre-engineering academic courses, including completion of AP calculus, mathematics, and science courses. Data displayed in Table 8 indicates that 82.5% of respondents had completed mathematics courses including trigonometry, and 70% of students had completed AP Calculus AB, the equivalent of a first-semester college calculus course, prior to attending the university. Significantly fewer students had completed AP Calculus BC, the equivalent to a second- semester college calculus course (College Board, 2016). These results reveal that within the sample, most subjects had taken advanced mathematics courses prior to enrollment in the university.

Data also indicates that most subjects had completed both physics (87.5%) and chemistry (92.5%) in high school. Slightly less than half (47.5%) had enrolled in AP physics. The data is presented in Table 6. High-school science courses are also part of academic preparations for a STEM major such as engineering. Table 6 indicates that most students had completed an AP course; however, less than 50% were enrolled in an AP Physics course (Table 7).

Table 6

Study Sample Mathematics Course Completion

Course	***n***	**%**
Trigonometry	33	82.5
Calculus	27	67.5
AP Calculus AB	28	70
AP Calculus BC	16	40
High-School Access to Courses		
AP Courses	39	97.5
College Courses	1	2.5

Self-Efficacy and MSLQ Scales

Table 7
Study Sample Science Course

Science course	***n***	%
Physics	35	87.5
AP Physics	19	47.5
Chemistry	37	92.5

The social cognitive theory applied to educational practices supports the belief that one can execute a course of action to produce desired results and attain success (Bandura, 1997). As young women interact with others in their learning environment, this self- perceived ability affects their perceptions of how they work in groups, think critically, and achieve in courses such as math and science. Participants in this study rated themselves compared to their engineering peers, both male and female, at the university level.

Self-perceived ability was computed as the average of items in question 17 obtained from the APPLES questionnaire; they are listed in Tables 8 and 9. Subjects were asked to rate themselves on their abilities as compared to their classmates using an ordinal scale of 1-5, where 1 = lowest, 2 = below average, 3 = average, 4 = above average, and 5 = highest. Most significantly, the data indicates that the mean of all respondents' abilities is defined as average, despite university GPAs that were identified in Figure 2 as above average. Respondents rated themselves as above average in both the ability to work in teams (M=4.15) and the ability to solve problems (M=4.05). Respondents generally rated themselves as average when compared to their peers in mathematics (M=3.78) and science (M=3.68). The frequencies, mean, and standard deviation for self-efficacy are found in Table 8.

Table 8
Study Sample Self-Perceived Ability

	n	***Min***	***Max***	***m***	***SD***
Overall ability	40	2.77	4.62	3.6808	0.43811
Math ability	40	2	5	3.78	0.698
Science ability	40	2	5	3.68	0.656
Critical-thinking skills	40	2	5	4	0.784
Problem-solving skills	40	2	5	4.05	0.749
Ability to perform in teams	40	3	5	4.15	0.662

Feelings of self-perceived ability obtained from the APPLES questions in the survey can be distinguished from the MSLQ self-efficacy measures. In examining the APPLES question data, no significant relationship was found between respondents' socioeconomic status and feelings of self-efficacy (Kruskal Wallis Test = 2.451, p = .653). The literature supports the fact that increased self-efficacy and STEM identity-development can be influenced by friendship groups and social supports that may not exist in lower socioeconomic status groups that may be at risk (Robnett & Leaper, 2013; Stoeger et al., 2013). These results are outlined in Table 9.

Table 9
Relationship between Self-Perceived Ability & Socioeconomic Status Test Statistics[a, b]

Socioeconomic Status	***n***	***m***	***SD***	***p*-value**
Low income	2	3.5769	0.59832	0.653
Lower-middle income	4	3.5769	0.4594	
Middle income	13	3.6568	0.4675	
Upper-middle income	16	3.6683	0.47478	
High income	5			
		3.9077	0.19911	

a. Kruskal Wallis Test
b. Grouping Variable: Would you describe your family as: (Mark one)

Motivation

Given the respondents' self-rating of average as compared to their peers, the researcher was interested in identifying university-level supports respondents utilized when they encountered academic difficulties. The small student-to-faculty ratio of 1:10 at the research site (see Table 2) means that students most likely have had opportunities to interact with faculty and utilize other academic supports for their persistence in engineering when they encounter struggles, such as the writing center, the Engineering Support Alliance (ESA), and mentors. Respondents reported utilizing the writing center and upperclassman mentoring most often to support their success (see Figure 7). It is also important to note that 18% of respondents did not utilize any support services offered by the university, succeeding on their own without assistance from formal or informal supports. Utilization of university supports is included in Table 10.

Table 10
Seeking Help from Peers

Engineering courses	***n***	***%***
Yes	38	95
No	2	5
Mathematics courses		
Yes	36	90
No	4	10

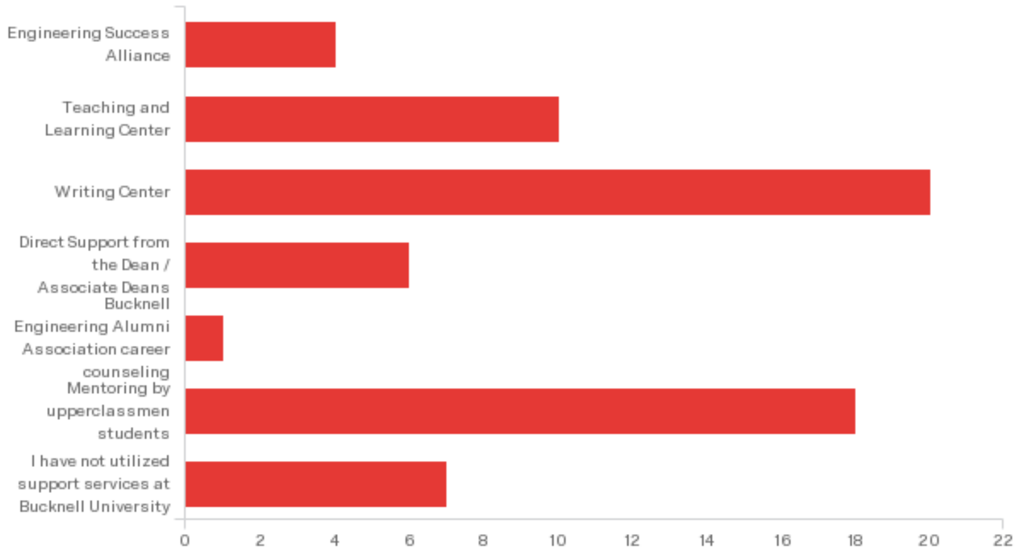

Figure 7. Participant utilization of university supports.

The following variables demonstrate resources utilized by those respondents who sought assistance. Among those who sought assistance, respondents were willing to seek help from professors (87.5%) and other engineering students (87.5%). See Table 11.

Table 11
Use of University Resources for Help

Professors		***n***	***%***	***Valid %***
	Yes	35	87.5	97.2
	No	1	2.5	2.8
Other engineering students				
	Yes	35	87.5	97.2
	No	1	2.5	2.8

Table 12
Cross-Tabulation GPA & Usage of ESA

GPA	***n***	***%***	***p*-value**
4.0-3.9	2	5	0.012
3.8-3.5	14	35	
3.4 - 3.2	8	20	
3.1-2.9	9	22.5	
2.8-2.5	5	12.5	
2.4-2.2	2	5	
Missing	*4*		

**Normally Pearson Chi Square is done, but since the expected count was less than 5, Fisher's Exact Test was utilized. Nine cells (75.0%) have an expected count less than 5. The minimum expected count is .20. The standardized statistic is 2.519.*

Given the data on support services utilized, there appears to be a significant relationship between respondents' GPAs and their utilization of the ESA for support (Fisher's Exact Test = 10.92, *p*=.010). As noted in the cross-tabulation in Table 12, those students who utilized the ESA appear to be more concentrated in the lower GPA levels.

Motivation and MSLQ Scales

Motivation is measured as the average of the four motivation items obtained from the MSQL inventory. Due to this study's small sample size, non-parametric tests were used when possible. The Kruskal Wallis test, the non-parametric equivalent to a one-way ANOVA, was used to assess for the possible presence of a relationship between motivation, respondents' parents' education, and family income. The Mann Whitney U, the non-parametric equivalent to the *t*-test, was used for the binary variables of race, "being the first-generation college student," and "having an immediate family member holding an engineering degree." Based on data collected from the 40 female participants, the self-rating for extrinsic goals show a mean of 4.12, while intrinsic goals show a mean of 3.92 (see Table 16). Both means fall within one standard deviation and are higher than self-efficacy as a source of motivation. There is no significant difference in motivation across the difference levels of mother's education (Kruskal Wallis Test = 2.663, p =.446). This data is presented in Tables 13 and 14. There is also no significant difference in motivation across the different levels of father's education (Kruskal Wallis Test = 4.326, p =. 228). This data is presented in Table 14.

Table 13
Motivation and Mother's Education Test Statistics[a, b]

What is the highest level of education your mother completed?	**%**	**p-**	
Graduated from high school	2	5	0.446
Completed an Associate's degree	5	12.5	
Completed a Bachelor's degree	20	50	
Completed a Master's degree	11	27.5	
Don't know or not applicable	2	5	

a. *Kruskal Wallis Test*
b. *Grouping Variable: What is the highest level of education that your mother completed?*

Table 14
Motivation and Father's Education Test Statistics[a,b]

What is the highest level of education father completed? (mark one)	**N**	**%**	**p-**
Graduated from high school	3	7.5	0.228
Completed an Associate's degree	1	2.5	
Completed a Bachelor's degree	19	47.5	
Completed a Master's degree	13	32.5	
Don't know or not applicable	4	10	

a. *Kruskal Wallis Test*
b. *Grouping Variable: What is the highest level of education that your father completed?*

This researcher was interested in exploring what motivations had influenced the participants to enroll in an engineering major to evaluate if a commonality existed within the study population that could be shared with the larger ethnographic group. Respondents indicated that teachers (32.5%) and family members (35%) were the most influential factors in their decision to major in engineering, with self as the next most important factor (25%). The least significant factor (2.5%) was having a mentor outside of the educational setting, as displayed in Table 15.

Given the closeness in the range of data among the influence of teachers, family, and self as motivation to enroll in an engineering major, it is important to compare whether intrinsic or extrinsic motivations are most influential for young women enrolling in engineering programs. To address this question, this researcher examined the intrinsic and extrinsic goal-motivation scales shown in Table 16. The mean for intrinsic motivation was 3.93 (SD=1.02), while the mean for extrinsic motivation was 4.13 (SD=.99). Both scales are moderately correlated (r=.515, *p*=.001), as shown in Table 16. There are no significant differences between the means of intrinsic and extrinsic motivations (*t*=-1.275, *p*=.210), as shown by the paired *t*-test in Table 16. In other words, we cannot say that one dimension of motivation is more important than the other.

Table 15

Significant Factors in Selection of Engineering Major

Factor	***n***	***%***
Teacher	13	32.5
Mentor	1	2.5
Family	14	35
Self	10	25
Other	2	5

**Identify the most influential factor in selecting engineering as a major.*

Table 16

Paired Samples Test

Intrinsic Goal & Extrinsic Goal Correlations	***N***	**Correlation**
	40	0.515
Intrinsic Goal - Extrinsic Goal	**Mean**	**SD**
	-0.2	0.99228

Qualitative Research Methods

In the qualitative phase of this study, the researcher chose to examine the retrospective perceptions of the young women as an ethnographic group by using a constructivist approach wherein the topic is explored with a group of people whose knowledge of that topic has been shaped by their individual experiences (Merriam, 2009). Ten survey participants were selected as a representative population; this purposeful sampling selection process attempted to mimic the ethnic background and minority representation of female engineering students at the research site. The focus group interviews were designed to draw out additional details about students' perceptions and feelings of self- efficacy during their K-14 academic careers. The questions were drafted at the beginning of the study, but minor changes occurred prior to administration since this study utilized a mixed-methods sequential approach and themes that emerged from the quantitative survey could not be predicted precisely. The participants were placed into two focus groups of five individuals each, and the groups were conducted in March 2016 at the research site. The focus groups were randomly assigned and were held in the same location; a half-hour break was incorporated between the first group's expected departure time and the second group's arrival time to protect participants' anonymity. All responses were recorded with a tape recorder and a voice memo for later transcription through the software package NVivo. These two recording methods helped mitigate the effects of technical difficulties encountered during the recording process. As an incentive to participate, students were provided with light refreshments and entered into a door-prize drawing for an Amazon gift card.

The participants in this study were viewed as persisting in engineering based upon their standing as either a junior or senior in the College of Engineering and the assumption that they would graduate with their respective cohort. This phase of the study allowed the voices of young women who had both persisted and navigated STEM, specifically the engineering pipeline, to be heard. These voices allow the research community to gain insight into the motivations, experiences, and viewpoints that have enabled young women to persist in engineering when other students have not.

Phase Two focused on participants' perceptions of mathematics, science, and skills competencies; the influence of family, faculty, and mentors as sources of motivation; interactions with peers; and the development of self-efficacy. Questions also addressed women's perceptions of high-school and college coursework, classroom experiences, formal and informal STEM experiences, and interactions with faculty that may have contributed to or discouraged their entrance and persistence in an engineering major. An exploration of K-14 interventions determined whether common experiences existed among focus group participants. Based on the findings, relationships between the independent variables were explored and themes were identified to determine possible relationships between female students' retrospective recall of experienced interventions and development of a STEM identity that led to their pursuit of a university engineering major.

Results and Interpretations

In a line-by-line hand-coding of keywords within the five interview transcripts, the following words emerged as most-frequently referenced by the participants: *science, different, classes, math, think, people, good, women, professor, time, fun,* and *experiences*. These keywords are aligned to support the six emergent themes for persistence categories revealed in the open and thematic coding: Influence of others, academic opportunities, motivation, mathematics, university experiences, and culture.

The focus group data revealed several common themes that resonated across all subjects, independent of participant ethnicities and/or cultures. Because of the study's small sample size, however, it is difficult to determine if these similarities are specific to this study or representative of a larger ethnographic group. Common motivation-related themes emerged from the qualitative phase of the study, specifically the intrinsic factors of self-motivation, including showing others they can do it, beating statistics as a first- generation college student and minority, knowing they need to work hard, and the intrinsic values of achieving what they set out to do by not giving up. All subjects indicated that the focus of their K-8 education had been predominately on mathematics rather than science, even at the different types of schools they had attended.

Several subjects also spoke about finding an interest in their abilities and making class fun during middle school, citing a connection to a teacher that had encouraged them to continue participating in challenging activities. Surprisingly, the individuals interviewed did not have access to many pre-engineering courses or expansive AP offerings, but they did participate in physics and advanced mathematics courses. The response most characteristic of the ethnographic group studied, even across ethnicities, was the young women's feeling of self-efficacy as demonstrated by their confidence in their abilities and determination to meet the challenges with which they were presented. This motivation for persisting in the study of engineering was more common among the participant statements than any other motivating factor.

Respondents' engineering-related opinions were positive, with helping others and making a good salary mentioned as rewards of completing the major and pursuing employment in the profession. Interviewees shared a common interest in the opportunity for future jobs, and they all clearly communicated a belief in their own ability to complete the program, even if they encountered difficulties and compared themselves to others around them.

Differences in participants' responses by race/ethnicity did exist, although there were more commonalities than differences. However, with such a small sample size, it is impossible to determine if these differences are related to racial/ethnic differences or are merely specific to this sample. One difference presented by the Asian American transfer student was that in her native country, there was not an option for girls to participate in robotics clubs but that that there was an expectation for every student to graduate and pass university entrance exams to get into the best colleges. She also indicated that her parents were engineers and that her environment had steered her into that major. The African American participant indicated that she had come from a home where she had beaten certain statistics. Comparing herself to others, she became determined to beat the odds and become an engineer so she could help others and make a good living.

Conclusions

Phase One findings from the Combined APPLES and MSLQ Perceptions and Motivations of Persistence in Engineering Survey indicated that respondents demonstrated above-average feelings of self-efficacy, with an average rating of 3.68 on a 1-5 scale, with 1 being the lowest and 5 being the highest. Interestingly, though the study participants rated themselves lowest on their mathematics and science abilities, they rated themselves significantly higher on their critical thinking, problem-solving, and teamwork abilities. No significant relationship was found between respondents' socioeconomic status and self-efficacy, and the same was true with the potential relationships between race and self-efficacy and parental education and self-efficacy.

This data supports the conclusion that as an ethnographic group, young women who persist in engineering have higher-than-average feelings of self-efficacy, independent of other demographic variables such as race, parental education, and socioeconomic status. This data was further supported by Phase Two of the study, which consisted of focus group interviews in which the women indicated their beliefs that they were as capable as their male peers to be engineers. The data was also reinforced by the respondents' attitudes, which were focused on their own beliefs that hard work and effort had resulted in their success in engineering degree programs.

In Phase One of the study, 39% of the respondents indicated higher-range GPAs (above 3.0), with most resting in the 3.5–4.0 range. There was a significant finding that students with lower GPAs had utilized the university's support program for engineers, the ESA, which is designed to support potentially at-risk students entering the engineering program. This data reinforces that the students who struggle academically are utilizing relevant support services. There was not enough variation in the sample to determine a relationship between AP courses taken in high school and respondents' current GPA. This lack of variation does affirm, however, that students entering the engineering program had enrolled in high-school AP courses as preparation for their fields of study, but that only 40% of students had had the opportunity to take AP Calculus BC, the second-semester equivalent of college calculus.

In Phase Two of the study, the focus groups revealed respondents' frustrations at the lack of AP mathematics and science courses available to them prior to college, explaining that they felt some of their college peers had more pre-engineering experiences or higher levels of AP mathematics coursework than they had been able to participate in before graduation. Every subject in Phase Two had completed at least one AP math course and one AP science course, however, further solidifying the conclusion that AP course preparation was a common high-school experience for this ethnographic group.

In Phase One of the study, the quantitative survey instrument revealed that respondents viewed extrinsic goals, with a mean of 4.12 on a 1-5 scale, and intrinsic goals, with a mean of 3.92, as relatively significant motivating factors. Both means fell within one standard deviation and were identified as more significant than self-efficacy as a source of motivation. In Phase Two of the study, motivation was further explored, with a question focused on identifying why the subjects believed they had persisted in engineering when other young women had not. In response, all the subjects indicated an unwillingness to leave a major field of study in which they felt they could succeed and would result in a rewarding career and support their desire to achieve difficult goals. Several participants also cited as motivators proving others wrong, having a sense of stubbornness, and being true to themselves. This intrinsic goal motivation was apparent in the young women's focus group responses, and evidence statements included in the qualitative data analysis referred to the presence of intrinsic goals among participants throughout the interviews.

It is important to examine grouping for all students, including young women, supports, and relationships, and attitudes of the educators that facilitate STEM identity- development, both formally and informally. The findings of the qualitative study indicate that most of the participants had determined they would pursue engineering during their middle-school years, supporting literature that indicates the decline in interest in STEM subjects begins as early as age 11, during the middle-school years (Stoeger et al., 2013). The participants in this study indicated that they had participated in and had access to AP courses but that few AP science courses had been offered at their school early in their academic careers. Furthermore, participants indicated an environment that was less supportive in high school than in the middle years, when subjects become increasingly difficult and students' perceived ability can waiver.

Implications

The present study has attempted to identify common themes in preparing young women for enrollment in an engineering major, as well as themes that support persistence within the ethnographic group of young women enrolled in an engineering major. This study serves as a starting point for meaningful dialogue at the K-14 levels about strengthening mathematics supports and opportunities available for young women in preparation for AP coursework. While it is apparent that the young women in the study have above-average self-efficacy about their ability to work in teams, solve problems, and think critically, the fact remains that their self-efficacy indicators are lower in core academic areas such as mathematics and science, even for those individuals who have persisted in the engineering field.

It is important for administrators and teachers to reinforce in the middle-school years that mathematics ability is learned and acquired, and that mathematics can be fun and engaging if a teacher takes an interest in his or her female students and helps them believe they can be successful. It is recommended to engage young women in more robotics and science competitions to establish a culture in which they can enjoy informal programs and where these activities are not perceived to be male-only clubs or activities, as was mentioned in the qualitative focus groups. It is also important to recognize that pre-engineering programs, although helpful, may not occur in schools around the country and that disparities exist in both pre-engineering programs and AP courses. The primary recommendation resulting from this study is as follows: We must consider young women to be an ethnographic group that needs to have intrinsic goal-setting fostered, feelings of self-efficacy developed, and mathematical achievement supported as early as middle school. We must also support young women in addressing the struggle of transitioning to the university setting and pursuing engineering degrees in the current model of education.

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