Exploering the Factors that Motivate Female Students to Enroll and Persist in a Collegiate STEM Degree Program

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Available at: https://works.bepress.com/rosemary_edzie/1/
Exploring the Factors that Motivate Female Students to Enroll and Persist in a Collegiate STEM Degree Program

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Abstract—In the United States, collegiate enrollment in science and engineering programs continues to decline, while European and Asian universities have increased the number of science and engineering graduates. In addition, there is a growing concern over too few females enrolling and persisting in collegiate science, technology, engineering, and mathematics (STEM) degree programs. Through increasing access to pre-collegiate STEM activities, providing a better understanding of STEM career choices, instilling of confidence in math and science, and establishing student and industry based mentoring programs, more female students will enroll and persist in collegiate STEM degree programs. This paper sets to explore the factors that influence and motivate female students to enroll and persist in collegiate STEM programs through an exploratory sequential mixed methods research framework. The framework has been formulated into a model that provides an insight into female decision to enroll and persist in collegiate STEM programs. Emphasis will be placed on the first phase of the research model, qualitative data collection.

Keywords—engineering education; females in STEM; mixed methods research

I. INTRODUCTION

In 2006, the American College Testing (ACT) organization, reported that over the past ten years, the percentage of ACT-tested students from the United States who said they were interested in majoring in engineering has dropped steadily from 7.6 percent to 4.9 percent, while the number of science and engineering graduates from European and Asian universities has increased [1-2]. Increasing female enrollment in collegiate STEM degree programs will help to address the national concern over the low number of domestic students enrolling in STEM degree programs. In 2007, the Committee on Science, Engineering, and Public Policy reported on the state of STEM Education in the United States expressing the urgency in addressing this issue as the domestic and world economies dependence on science and engineering continues to grow. But our primary and secondary schools do not seem able to produce enough students with the interest, motivation, knowledge, and skills they will need to compete and prosper in the emerging world [3]. According to the 2009 U.S. Department of Commerce Economics and Statistics Administration Census report, more than half of college graduates are female (54.7%). However, females are earning less than a third of the collegiate degrees in STEM programs with the majority (78.5%) of females earning degrees in education. While their male peers account for less than half of the collegiate student population, males are earning 87% of the collegiate STEM degrees [4].

Regardless of the increased enrollment of females in collegiate degree programs, male enrollment in STEM programs continues to surpass female. In an effort to see why some STEM majors recruit a high percentage of female students, despite the national average, a pilot study of female enrollment trends in engineering was conducted at the University of Nebraska – Lincoln. The focus was placed on the Architectural Engineering (AE) program as it traditionally enrolls a high percentage of female students as compared to other engineering programs. The AE program is a five-year program where students graduate with a master in architectural engineering with emphasis in an area of specialization (lighting/electrical, mechanical, structural, and acoustics). The AE program, on average, has an enrollment of 200 students with almost half (46%) are female. In spring 2013, a study was conducted on an existing class of sophomore AE students enrolled in The Elements of Electrical Engineering (ELEC 2110) course, which is the first electrical engineering course in the curriculum, where students take this course in the fourth semester (second year).

It was found that over the past three academic years (2011, 2012, 2013), the population, in terms of gender, shows the number of female students is lower than that of the male students (2011: (9) Female, (48) male students; 2012: (12) female, (36) male; 2013: (5) female, (41) male). This data is shown in Fig 1. However, the female students perform relatively better than the male students in the class. The grade distribution of the female students, in Fig 2, shows that a greater number of female students received an “A” grade in the course, and none failed the class for three consecutive years. The performance has been improving over the years; higher number of “A” grades every year and reduced number of lower grades than previous year. When compared to male students’ grade distribution, the female students fared better than their male peers, as shown in Fig 3. The graph demonstrates the performance of both male and female
students for three years in the class. The bubble sizes represent the percentages of the students. Female students have consistently received more “A” grades than their male peers.

Fig 1. Demographics of course gender for the last three years.

Fig 2. Female student grade distribution for the last three years.

Fig 3. Student grade distribution for the last three years.

The result of this pilot study along with documented data from other classes led the researchers to conclude that females have the aptitude to be just as if not more successful than their male peers when enrolled in collegiate STEM degree programs. However, this finding does not address the national concern that there are too few females enrolling and persisting in collegiate STEM degree programs.

The review of literature proposed many factors, but it did not fully address what influences and motivates female students to enroll and persist in collegiate STEM degree programs. For example, Rinn et al. (2008) called for additional exploration to address why females fail to enter STEM fields at rates consistent with their abilities and male peers [5]. Additionally, Pajares and Miller (2006) did not provide the reader with an answer as to why differences exist in the levels of anxiety experienced by males or females, causing the researcher to question how males are developing higher levels of self-efficacy and self-concept and lower levels of anxiety and females are not [6]. Leslie et al. (1998) recommended that future research consider the factors that are causing females to lose self-confidence in their academic abilities in math and science [7]. Hackett (1985) concluded that mathematical self-efficacy, the level of anxiety experienced, and the likelihood of enrolling in a collegiate math-related major are influenced by two factors: gender-related socialization and the level of preparation in mathematics. What is missing from these studies is an understanding of which pre-collegiate factors contribute to pre-collegiate female students’ likelihood of enrolling and persisting in collegiate STEM programs [8].

Past research has looked at the factors that may affect a female student’s decision to enroll in collegiate STEM programs. However, none provided enough insight or a solution to the problem of female enrollment and persistence in collegiate STEM degree programs. This study is designed to address this area by exploring the factors that influence and motivate female students to enroll in collegiate STEM degree programs. Specifically, explore the effects of pre-collegiate STEM experiences on female student likelihood to enroll and persist in a collegiate STEM degree program through a mixed methods research approach. It is hypothesized that through increased pre-collegiate exposure to math and science academic fields there will be an increased likelihood of pursuit of a STEM collegiate degree program. It is expected that at the completion of this research, the study will provide significant knowledge for local, national, and federal stakeholders to the benefits and interest in increasing female enrollment in STEM programs. The study will provide a greater understanding of the factors that affect a female student in her decision to enroll in a STEM program and generate a female focused math and science extra-curricular and mentoring opportunities, STEM retention and persistence programs, an increase in female student interest in STEM programs, and a greater understanding of the impact of pre-collegiate STEM programs on female student self-efficacy, interest, and persistence.

This paper is organized as follows: Section II will provide an overview and of the research approach undertaken to understand female STEM approach; Section III will discuss the first phase of this study, the qualitative approach; Section IV will provide an analysis of the collected qualitative data; finally, Section V will provides the summary and conclusion.
II. OVERVIEW AND RESEARCH METHODS

The research study was structured as an exploratory sequential research design model that began with a qualitative exploration of pre-collegiate math and science experiences had by first year female collegiate freshman that have declared as a STEM major. Focus groups served as the means for collecting qualitative data. The focus groups were hosted at Midwestern University (MU), which is a land-grant institution that is listed with the Carnegie Foundation as having very high research activity. Following the collection and analysis of qualitative data, quantitative data will be collected, which will involve the administering of a survey, that will serve as the tool for testing for levels of female confidence and persistence as they relate to STEM degree programs. The quantitative research questions and hypothesis will be formulated after the completion of the initial qualitative phase. The reason for collecting the qualitative data initially is so that there is an opportunity to expand upon a pre-existing survey so that the research problem can be fully addressed.

In the proposed research study, the application of a sequential exploratory mixed methods approach to the research design will provide for the opportunity to organize the gathering of data into four phases (as shown in Fig 4): (I) collection and analysis of qualitative data through participant engagement in focus group session; (II) review of the qualitative findings that were then used to develop a survey instrument; (III) collect and analyze quantitative data which involved administering the newly developed survey that was the combination of two independent surveys to the sample population. The two surveys involved in Phase III will include: (a) a survey that was the product of findings from the qualitative phase, Phase I, and (b) the second survey was the pre-existing Motivated Student Learning Questionnaire (MSLQ); and, (IV) synthesis of the findings. The remainder of this paper will focus on Phase I of the research study, qualitative data collection.

III. COLLECTION OF QUALITATIVE DATA THROUGH ENGAGEMENT IN FOCUS GROUP SESSION

In Phase I of this study, qualitative data were collected through the engaging of participants in a focus group setting. Constructivism was the theoretical framework that guided this phase. Broadly, the constructivist theoretical framework assumes that multiple realities exist, and that we construct the meanings of experiences through interaction with others [9]. Qualitative research is, as Creswell (2009) explained, a means for exploring and understanding the meaning individuals or groups ascribe to a problem [10].

The collection of qualitative data was focused on investigating the participants’ phenomenological understanding of the experiences that influenced their enrollment in collegiate STEM degree programs. The first phase involved the purposeful sampling of undergraduate female students to participate in focus group sessions. Creswell and Plano Clark (2007) described purposeful sampling as choosing participants that had experience with the concept being explored [11]. The sampling of participants involved soliciting involvement from a pre-determined demographic to partake in a focus group session. The pre-determined demographic was defined as: female undergraduate student, categorized as a first-year female freshman (0-26 credit hours), and enrolled in a collegiate STEM program.

The primary method for qualitative data collection was through participants sharing their experiences in a focus group session. Krueger (1994) wrote that the goal of the focus group is to gain insight into attitudes, perceptions, and opinions of participants and that there are six characteristics of a focus group described as involving people (6 to 10); assembling a series of groups; possessing certain characteristics; resulting in data; structured in a qualitative manner, and; facilitating a focused discussion [12].

The focus groups were limited in size to six participants so that there was (1) sufficient time to hear from everyone; (2) comfort felt by participants when sharing insights; and, (3) diversity among participants [12]. Four focus groups involving first-year female freshman enrolled in collegiate STEM programs at MU were hosted. There were two focus groups hosted on each campus of MU. Each focus group session was 60 minutes in length, including time for introductions. The first two meetings were hosted on the flagship location of MU, and the second sets of meetings were hosted on the metropolitan campus. Both MU campus locations offer collegiate STEM degree programs. To recruit focus group participants, an email message was sent to all female first-year freshman students (N = 265) enrolled in a collegiate STEM degree program at MU inviting them to participate in a focus group session. Approximately 5% (N = 13) partook in the focus group sessions during fall and winter 2012.

The majors represented in the focus group included Actuarial Science (N = 1); Architectural Engineering (N = 5); Biochemistry (N = 1); Biological Sciences (N = 3); Biology/Pre-Medicine (N = 1); and, Computer Engineering (N = 2). Eleven of the participants reported their race as white while 2 classified as Middle East/Oman and African American/Black. All focus group participants reported that the Highest-Level of Education in their family is at least a four-year college degree and 12 of the 13 participants reported their Socio-Economic
Status (SES) as at least middle class with 42% as Upper-Middle class. When asked to report Mother’s Highest Education received, 85% reported at least a college graduate and for Father’s Highest Education received, 77% reported at least a college graduate. Table 1 provides a summary of the participant’s demographics.

**TABLE I. FEMALE STUDENT DEMOGRAPHICS**

<table>
<thead>
<tr>
<th>Major</th>
<th>Highest Level of Education in Family</th>
<th>SES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actuarial Science</td>
<td>Four-Year College Degree</td>
<td>Middle</td>
</tr>
<tr>
<td>Architectural Engineering</td>
<td>Doctorate or PhD</td>
<td>Upper-Middle</td>
</tr>
<tr>
<td>Architectural Engineering</td>
<td>Four-year College Degree</td>
<td>Middle</td>
</tr>
<tr>
<td>Architectural Engineering</td>
<td>Four-year College Degree</td>
<td>Lower-Middle</td>
</tr>
<tr>
<td>Architectural Engineering</td>
<td>Graduate or Professional Degree</td>
<td>Upper-Middle</td>
</tr>
<tr>
<td>Architectural Engineering</td>
<td>Graduate or Professional Degree</td>
<td>Upper-Middle</td>
</tr>
<tr>
<td>Biochemistry</td>
<td>Graduate or Professional Degree</td>
<td>Middle</td>
</tr>
<tr>
<td>Biological Sciences</td>
<td>Four-Year College Degree</td>
<td>Middle</td>
</tr>
<tr>
<td>Biological Sciences</td>
<td>Doctorate or PhD</td>
<td>Middle</td>
</tr>
<tr>
<td>Biological Sciences</td>
<td>Four-Year College Degree</td>
<td>Middle</td>
</tr>
<tr>
<td>Biology/Pre-Medicine</td>
<td>Four-Year College Degree</td>
<td>Upper-Middle</td>
</tr>
<tr>
<td>Computer Engineering</td>
<td>Graduate or Professional Degree</td>
<td>Middle</td>
</tr>
<tr>
<td>Computer Engineering</td>
<td>Graduate or Professional Degree</td>
<td>Middle</td>
</tr>
</tbody>
</table>

For this phase, 13 open-ended questions were developed (as shown in Table II) and directed to the group as a means for starting a discussion of their math and science experiences. The questions were structured so that the conversation began with a general discussion of participants’ experiences and as the participants grew more comfortable with sharing their math and science knowledge in the group dynamic, the questions asked became more specific to personal pre-college experiences and long-term career plans. The unfocused conversation provided additional insight into which factors influenced their decision to enroll in a STEM program as well as revealed unexpected characteristics of the demographic [13].

**TABLE II. FOCUS GROUP QUESTIONS**

- Why did you enroll in a STEM program?
- Did you consider any other programs when looking at colleges?
- Was there a particular moment that stands out for you when you decided that this was the right major for you?
- What do you like about science and math?
- Did you participate in a pre-engineering and technology curriculum in high school? For example, a magnet math and science or Project Lead the Way school.
- Did you participate in math and science focused after school programs or camp activities?
- Did you participate in any STEM related programs in high school?
- Do you think that males go into STEM for the same reason as females?
- Does it matter if you impact others?
- What do you think educators can do to encourage more females in math and science – STEM?
- How do you feel if you get a B on a homework or exam after you worked really hard to prepare for it?
- What motivates you to persist in this major?
- What are the top 3 reasons for why you choose this major?

IV. ANALYSIS OF THE COLLECTED DATA

The results of the qualitative data are formulated into a model, as shown in Fig. 5, that identifies the Influential Factors for Females in STEM Collegiate Degree Programs. This model demonstrates the components that were identified as influencing and motivating female students to enroll and persist in a collegiate STEM degree program: Altruistic; Career Security; Confidence to Enroll and Persist; Influential Decision Maker; Passionate about STEM; Pre-collegiate STEM Exposure; and, Prestige STEM Outlier. The model represents the key components shared by first-year female freshman when asked why then enrolled in a collegiate STEM degree program.

![Fig 5. Influential Factors for Females in STEM Programs](image)

One female participant shared that she really fell in love with math and science when she was little. While another participant expressed the particular moment that stood out for her as affecting her passion for STEM as [I] started loving sciences when I started getting good grades in it. Other participants acknowledged that they were influenced by the passion had by others. One participant shared how her parent served as an influential decision maker. While another participant shared how her physics teacher’s excitement engaged the class as my physics teacher is the one who influenced me the most in science. He loved it and he would start explaining then he’d keep explaining past what he should have stopped at. We’d be learning more and more and more. I was one of 2 girls in my AP physics class. He didn’t treat us
any differently and he explained everything to us the same as
the rest of the class. There was a little separation with the rest
of the class when grouping because we’re girls. Other than
that, all the teachers that I had have treated the whole class
the same because we were all there to learn.

Of the 7 themes explored in Phase I of the research study,
four (Altruistic; Confidence to Enroll & Persist; Influential
Decision Maker; and, Pre-collegiate STEM Exposure) will be
addressed in the next section.

A. Altruistic

According to a report from the Girls Scout Research
Institute, 90% of girls want to help people and make a
difference in the world; yet only 13% of them identify a STEM
career as a way to make that dream a reality [14]. Almost a
third of the focus group participants spoke of their desire
to have a career where they made a difference in the lives of
others. One participant shared, I love biology, because of the
future, all of the great things that can come out of being a
doctor. The extremely comfortable life style, the getting to help
people, there’s a lot of benefits. Some participants’
aknowledged that their contributions better society even
though it may not be apparent. An architectural engineering
student reflected, people don’t come into this room and say,
they did a really good job making sure this room can stand up
with the structure and temperature. They don’t think about that;
you’re affecting them even though they don’t realize it. Another
student shared, I want a job where I can help people and I’m
taking care of people; which was echoed by her peer, I’m a
people person. I like people. I want a job where I can help
people and I’m taking care of people.

For one student, she did not realize that she would be
helping others until she enrolled in her first semester and her
professor shared that [her professor] always talks about how
people look at insurance as bad, but in a way, he always looks
at it as you are helping people because you’re going to make
sure that they can afford the stuff that they couldn’t afford
before that.

B. Confidence to Enroll and Persist

Focus group participants were asked about what
motivates them to persist when they are feeling overwhelmed
by homework, work, and other external factors. Overwhelmingly, female participants shared how their passion
for math and science and career goals kept them motivated.
One participant shared I love biology, for whatever reason. I’ll
take whatever else I have to take to get to it. I’ve always
wanted to go to medical school. While one participant shared
how she overcame the struggles of a difficult course as: I’m
not going to lie, I really struggled in Calculus last year and
thought, if this is what it’s going to be like and I have to
struggle every single day, I don’t know. Struggles are part of
life and I looked past it...it’s more focused on the ultimate goal.
You have to keep focus that it gets better, I can do this. I think
they go hand in hand, getting good grades and the confidence.
Obviously, if you get bad grades, you’re not going to have the
confidence there. But there’s still people who get good grades
but still don’t have the confidence to do it. One doesn’t cause
the other; you have to have both.

Another participant shared how she overcame the
frustrations of not succeeding as A bad grade just told me I
needed to take on the challenge more. I didn’t feel necessarily
discouraged; I just needed to work harder because I know that
I can do it. That I can do better so I need to work harder. One
participant said our teachers have always pushed on us,
young independent thinking women, leaders. That’s the values
they’ve always instilled in us, that we can do whatever we want
and succeed. For one participant, the confidence to persist
despite obstacles faced comes from her mother.

C. Influential Decision Makers

There were 2 primary influential decision makers, (a)
parents and (b) teachers who affected the participant’s
decision to enroll and persist in a collegiate STEM degree
program.

a) Parent. Overwhelmingly, participants shared that
either their mom or dad worked in a STEM field and that
having access to these careers influenced their decision to
enroll; dad is a civil engineering so when I was in 7th and 8th
grade, I loved making floor plans. I was like; I’m going to be an
architect! Obviously, being an engineer he was like, No! You
can’t be an architect! How about architectural engineering? I
said, Yeah, that’s exactly what I’m going to do. (Focus Group
Participant). One participant shared, I always knew I loved
math...[my parents] had talked about engineering... it was a
field, not a lot of girls were in and there were definitely
scholarships for it. When I finally figured it out, it was the best
option for me.

b) Teacher. One participant recalled the experiences she
had as a sixth grader in math that influenced her collegiate
major decision The last time I had a woman math teacher as in
sixth grade; she was my favorite teacher. That was when I
realized I was good at math. When I was getting over 100% in
class, she actually moved me up a grade in math, so that
definitely started my process. After her I’ve had all male
teachers; it’s been an all male field for me. The excitement had
by teachers in the classroom affected one student, as she
recalled, ...our chemistry teacher was the greatest; she made
me love chemistry. She was one of those inspiring people. I
talked to her a lot about what I wanted to go into and how hard
it was. She said, you can do it. She got everyone to put forth
their answers and participate in class so that was helpful. For
one female student, taking time to meet with her teachers to
talk through her interests influenced the major that she
choose, I didn’t really know what it was until I sat down and talked to my physics teacher and my guidance counselor about it [which major to explore] I want to do architecture, but I really want to involve more math and science…I’ve always had math and science there and so I don’t want to just drop it behind.

D. Pre-Collegiate STEM Exposure

Focus group participants were asked to share their pre-collegiate STEM experiences that ranged from attending a STEM magnet school, participating in STEM after school programs or camps, and partaking in STEM related programs in high school. Focused group participants shared that they attended architectural engineering camps, enrolled in construction and drafting class, participated in robotics competitions, attended math days at the university, and partook in high school field trips to science labs.

One female participant shared how she participated in a field trip to a [science] lab where students listened to five different people who work in different parts in that lab…they do something with blood and our science teacher took us there so we could see different opportunities and if we would like to work there sometime. It was interesting to learn about career opportunities out there and how you can apply science. Another focus group participant shared that in [her] anatomy class for dissecting cats, we had a race. There was a group of girls and a group of boys. Sometimes the girls would win and sometimes the boys would win.

V. SUMMARY AND CONCLUSION

This research project explored the factors that influence and motivate female students to enroll and persist in collegiate STEM programs through an exploratory sequential mixed methods research framework. The key influential factors found to influence female enrollment and persistence in collegiate STEM degree programs included a call for focusing on the altruistic nature of a STEM career; increasing confidence in females at an early age through access to math and science courses; providing females with information about careers in STEM by linking discipline and employment; and, increasing pre-collegiate STEM exposure through hobbies and academic experiences. Future research will explore the key influential factors on a larger scale by increasing the sample population size and integrating a survey to gather quantitative data.

REFERENCES