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Becoming Female Engineers and Engineering Educators: A Qualitative Study of Female PHD Students

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ABSTRACT

The engineering profession is traditionally male-dominated. Female engineers only occupy a small portion of positions in the profession, particularly upper management and educators' positions. This study explores the motivations and career perspectives of female engineers and engineering educators' intentions of joining the engineering field as female professionals. Based on social cognitive career and motivation theory, the current study was guided by two research questions, why do female professionals want to join the engineering industry as engineers and engineering educators, particularly after completing their PhD degrees? What are their motivations, and how do female professionals describe their experiences, career decision-making processes, and problems as women in the engineering industry, as engineers and engineering educators? With the interview sessions and focus group activity, eight female engineering PhD students were invited. The finding indicated that academic interests and interests in career development were the main influences. The results of this study may provide recommendations to female students, university leadership, department heads, lecturer, government leaders, and policymakers to reform and polish the curriculum plans, human resources strategies, and gendered schemes for female engineers and engineering educators.

Keywords: engineering educator, engineering shortage, engineering student, female engineer, female engineering educator, social cognitive career and motivation theory, workforce

INTRODUCTION

In the United States, the fields of engineering and engineering education are in need of qualified and experienced engineers and engineering educators, regardless of subject matter and direction, particularly female engineers (Sharma et al., 2019). Although government agencies have established plans and schemes to encourage secondary school graduates, university students, university graduates, and second-career changers to join the field, there are still gaps in human resources and workforce management (Trigo et al., 2017). There are no laws or regulations restricting individuals from joining any occupation or career pathway in the United States, except for occupations requiring clear criminal records (e.g., teaching). However, due to social bias and social stigma, female individuals tend to avoid the fields of science, technology, engineering, and mathematics (STEM), as the general public believes related occupations are exclusively designed for men (Booy et al., 2012; Hughes et al., 2017). Because of this bias from the public, female individuals psychologically set up personal restrictions when they select university programmes during secondary school and their area of career development after graduating from university (Dos Santos, 2021b).

Traditionally, STEM fields are largely occupied by male staff and professionals due to social bias and social stigma. However, many studies (Botella et al., 2019; Diekman et al., 2017; Moss-Racusin et al., 2018) have indicated that the skills and abilities of women are at the same level as their male counterparts. According to a recent government report, workforce management between men and women is unbalanced in STEM fields. In architecture and engineering occupations, the percentage of female professionals in the workforce is relatively low, including architects (28.2%), material engineers (25.5%), industrial engineers (23.4%), chemical engineers (19.4%), computer hardware engineers (18.4%), civil engineers (16%), other engineers (15.3%), electrical and

electronics engineers (11.8%), aerospace engineers (11.6%), and mechanical engineers (8.7%) (*Labor Force Statistics from the Current Population Survey*, 2020). The low percentage of female engineers is an international issue. In the mid-2010s, less than 20% of the engineers in Australia were women. The percentage was even lower in Japan, where only 2% of engineers were women (Balakrishnan & Low, 2016; Strachan et al., 2018). Although these percentages do not reflect all social and psychological decisions, as individuals are free to select their area of career development and achievements, the above statistics indicate the imbalance in gender in engineering.

THE PURPOSE OF THE STUDY

This study explores the motivations and career perspectives of female engineers and engineering educators' intentions of joining the engineering field as female professionals in the United States. The engineering profession is traditionally male-dominated; female engineers only occupy a small portion of positions in the profession, particularly upper management and educators' positions (Cardador, 2017). However, it is important to balance gender diversity in engineering, as female professionals should have the same rights as their male counterparts. More importantly, the public images and reputations of female engineers and engineering educators may further encourage female students and second-career changers to join the engineering profession to fill up the long-term human resources and workforce gap in the field. Based on social cognitive career and motivation theory (Dos Santos, 2021a; 2021c; Lent et al., 1994), the current study was guided by two research questions:

1. Why do female professionals want to join the engineering industry as engineers and engineering educators, particularly after completing their PhD degrees? What are their motivations?
2. How do female professionals describe their experiences, career decision-making processes, and problems as women in the engineering industry, as engineers and engineering educators?

Theoretical Framework: Social Cognitive Career and Motivation Theory

Social cognitive career and motivation theory (Dos Santos, 2021a; 2021c; Lent et al., 1994) guides the direction of this study. The theory was developed based on the directions of social cognitive career theory (Dos Santos, 2019, 2020, 2021; Lent et al., 1994) and the self-efficacy approach (Bandura, 1982). Social cognitive career theory advocates that individuals' motivations, reasons, and career decisions may be inter-connected with different factors and elements both internally and externally. Motivations, reasons, and career decisions form complex combinations and may be influenced by a single factor or by multiple factors. In short, social cognitive career and motivation theory advocates two directions, including psychological and internal factors with self-efficacy with 1) academic interests, 2) personal considerations, and 3) achievements of education and career goals; and social and external factors with 1) interests in career development, 2) financial considerations, and 3) surrounding environments and individuals.

METHODOLOGY

As this study collected intensive information and lived stories (Tang & Dos Santos, 2017) from the participants, the researcher employed interpretative phenomenological analysis (Smith et al., 2009) as the study's methodology. The interpretative phenomenological analysis (Smith et al., 2009) advocated that lived stories and sharing from a small group of individuals always provide the in-depth and rich understanding and background for the targeted issues. For some social issues, such as female engineering students' career motivation and development, it is important to understand the in-depth background and previous stories (in order to gain the holistic picture). Therefore, the selection of interpretative phenomenological analysis (Smith et al., 2009) would be appropriate.

Participants

The researcher employed the snowball sampling strategy (Merriam, 2009) to recruit the first participant for this study. The researcher sent the email with the purpose of this study, data collection protocol, potential risks, consent form,

and contact information to the participant. The participant officially agreed with the participation and signed the consent form with email confirmation. Due to the snowball sampling strategy, after the participant completed the first interview session, the participant was encouraged to refer at least one potential participant for further development. As a result, after several rounds of referral, eight participants were willing to join. The participants should meet all of the following elements to join the study, 1) Americans, 2) currently enrolled PhD in engineering student regardless of the location of the university, 3) female professional, 4) want to join the engineering profession or engineering education after PhD graduation, and 5) willing to share the lived stories about the engineering voyage as female professional.

DATA COLLECTION

Qualitative researcher (Seidman, 2013) indicated that in-depth understanding and lived stories sharing required multiple data collection sessions. Therefore, the researcher employed three private and semi-structured interview sessions and two sessions of focus group activity. The first interview session concerned the ideas about their pre-university understanding and lived stories as female students. The second interview session concerned the stories of their undergraduate voyage and the period before their PhD studies. The third interview session concerned about the voyage and stories during their PhD studies. Each interview lasted from 99 to 132 minutes. The focus group activity focused on the overall ideas with open-ended questions. The focus group activity lasted 167 minutes with two ten-minute breaks. Due to the COVID-19 Pandemic, the interview sessions and focus group activity were hosted online with the distance-based cellphone application (i.e. Whatsapp). All participants agreed with this arrangement.

After all participants completed their data collection procedure, the researcher transcribed the voiced messages to written transcripts. The sharing and lived stories were categorised based on each participant. The researcher sent the related and personal written transcript (based on each participant) back to each participant for confirmation. The researcher set up the member checking interview for confirmation. All participants agreed with their own sharing. The member checking interview sessions lasted from 32 to 45 minutes. The researcher employed the digital recorder to record the interview sessions, focus group activity, and member checking interviews. Only voiced messages were marked. All participants agreed with this arrangement.

DATA ANALYSIS

The researcher re-read the written transcripts multiple times for the potential themes and subthemes. The researcher employed the open-coding strategy to merge any potential sharing and lived stories into meaningful themes and subthemes as the first-level themes. From this stage, the researcher merged 13 themes and 14 subthemes. However, the first-level themes should be further developed. Therefore, the researcher employed the axial-coding technique. As a result, two themes were yielded as the second-level themes.

Human Subject Protection

The privacy of the personal background is the most important element in this study. Therefore, the researcher tried his best to protect all information from the participants. The signed consent form, personal information, age, skin colour, university information, grades, language, birthplace, personal contact, voiced messages, written transcripts, computer, and related information were locked in a password-protected cabinet. Only the researcher could read the information. After the researcher completed the study, the related materials were deleted and destroyed immediately. The study was supported by the Woosong University Academic Research Funding 2021.

RESULTS AND DISCUSSION

After 24 rounds of in-depth interview sessions and two sessions of focus group activities, the researcher had collected rich qualitative data from eight female PhD students (N = 8) who intended to join the engineering profession as engineers and/or engineering educators after graduating. Although none of the participants knew each other prior to the study, many shared similar perspectives and understandings of their

motivations and career decision-making processes.

Academic Interests: I Enjoy STEM with Strong Self-Efficacy

All eight participants expressed their strongest interest as being in engineering and related STEM subject matter and career development. First of all, all eight participants expressed how their interest in STEM subjects began during secondary school. As many participants loved STEM subjects and related lab activities, many had high levels of self-efficacy (Bandura, 1995), with good grades, as shown in the following comments.

…I was a science club leader in my secondary school…I won several science awards when I was young…I really enjoyed sciences because I think it is fun and not hard to remember…I gained a lot of pride…and awards from my teachers, schools, parents, and classmates…because I won a competition…I knew I could continue with this study…and I will receive good rewards from my parents and teachers…(Participant #1, Interview)

…learning science wasn't my interest when I was in primary school…I like Scottish and English literature…but when I was 14 years old…my biology teacher taught us how to…conduct the experiment in the biology lab…I received 100 and A for the biology class with the interesting lab experiment…after that, I want to exercise my energy and ideas to biology…now, in biotech engineering…(Participant #4, Interview)

According to social cognitive career and motivation theory (Dos Santos, 2021a; 2021c; Lent et al., 1994), psychological and internal factors regarding self-efficacy play an important role in people's career motivations and decisions. Their positive experiences in secondary school significantly increased the self-efficacy and academic interest of the participants. In line with previous studies (Ballen et al., 2017; Hushman & Marley, 2015), when individuals received positive results on tests, they were more likely to continue with their studies in the subject at hand. Especially for teenagers and young adults, who completed different courses and lessons in traditional school environments, many understood their academic interests and the disadvantages of some subjects. Many decide to pursue a certain subject, such as engineering, as their university major or as an academic programme because they know they will receive rewards and high levels of self-efficacy from the results of doing so. The high levels of self-efficacy achieved as a result of positive results in their courses may have eventually led to their academic interests and long-term career development – in this case, as engineers and engineering educators (Lam & Santos, 2018).

Interests in Career Development: Engineers and Engineering Educators

Many scholars have argued that men and women have the same level of abilities and achievements in mathematics and science subjects. One of the limitations separating men and women is the social bias regarding their gender (Singh et al., 2020). According to a recent project (*K-12 Education*, 2021), less than 30% of science and engineering human resources and workforces are women. Although 48% of biological, agricultural, and environmental science university student enrolments consist of female students, only 15% and 26% of those student enrolments are in engineering and mathematical sciences, respectively. In other words, a large gap in terms of gender diversity needs to be filled. When the researcher asked the participants about their motivations and reasons why they had selected engineering and engineering education as the area of their life-long career development, many indicated that their interests in practical engineering professions and engineering education (i.e., their life-long and long-term achievements and career goals) played a role. Two comments were captured in this respect:

…I want to teach engineering…I want to become a teacher in school…but I think university lecturers for adults…are better for secondary school teaching…I want to help patients with disabilities…I used to think about health promotion or physical health…but what if I can combine the medical knowledge to engineering…therefore, I joined biomedical engineering…for the equipment and healthcare materials…now, I want to transfer the knowledge and design our medical equipment to

the industry and host my lab…for our junior-level students…(Participant #6, Interview)

…animal and agriculture are some raw industries that need professional development…many animals, such as cow, suffer from the negative environment…farmers don't understand how to operate the farm and care their livestock…we have to teach our farmers, agricultural students, and even butchers…the positive management for animals…I am improving the cow brush for animal's stress…I hope I can teach the farmers and transfer the knowledge to our agricultural engineering students…(Participant #2, Interview)

According to social cognitive career and motivation theory (Dos Santos, 2021a; 2021c; Lent et al., 1994), personal considerations (e.g., psychological and internal factors concerning self-efficacy) and interests in career development (e.g., social and external factors) echo the motivations and reasons underlying individuals' engineering and engineering education career developments. A previous study (Balta et al., 2017) advocated that personal interests and previous experiences may increase individuals' motivations and enhance their career decisions, particularly in engineering pathways, as many secondary school students do not have daily experience in engineering subjects. In other words, the early introduction of engineering subjects will increase the likelihood of individuals joining engineering and engineering education. More importantly, the connection between personal interests and engineering subject matter is the key to enriching motivation (Chou & Chen, 2017).

CONTRIBUTIONS AND CONCLUSION

First, female students and engineering students will be beneficial from the study. It is not hard to believe that many female students want to achieve their STEM degrees and career development in male-dominated fields. However, due to social bias, many women give up their career goals and achievements. The finding of this study provides the guidelines and recommendations from a group of PhD students in engineering studies, particularly how can they overcome the gendered issues. Individuals and groups may take this study as their guideline and counselling materials to plan their goals and career decisions.

Second, university leaders, faculty heads, and university lecturers may use this study to guide curriculum development. Although STEM subjects and academic programmes have higher-level of male student enrolment, it does not mean these academic programmes are exclusively designed for male students. Educators may establish schemes and plans to engage and encourage the connection and potential enrolment of female students.

Third, government departments and policymakers should take this study as the blueprint to reform and polish the current human resources planning and issues for gendered bias. Based on the current statistics, many female engineers and professionals face discrimination and gendered bias due to their biological and physical characteristics. Without the plans and programmes from the government departments will not improve the problems in the current workplace environment. Therefore, based on the sharing and lived stories from a group of female professionals, the government should take steps in order to change and improve our society.

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