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EXPERIENCE OF WOMEN IN ENGINEERING EDUCATION: LITERATURE REVIEW

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ABSTRACT

Despite significant improvements in the last couple of years, women are still under-represented in science and technology, both in the academic and private sector. This is due to a variety of reasons, mostly related to the role allocated to women in modern society as well as pre-existing biases and women's perceptions of commitment to engineering careers. The purpose of this paper is to evaluate experience of women in engineering education in various countries by reviewing research works which is done by researchers related to experience of women in engineering education at different outlooks that can help to have ideas about the trends of women in the field as well as what are the barriers that makes women being underrepresented in engineering education. As such the author concludes that these reviewed papers indicates that there is underrepresentation of women in engineering education in various parts of the world, even if there is some improvement.

Keywords: Women, Engineering Education, Literature review

Introduction

The number of women in science and engineering is growing, yet men continue to outnumber women, especially at the upper levels of these professions. In elementary, middle, and high school, girls and boys take math and science courses in roughly equal numbers, and about as many girls as boys leave high school prepared to pursue science and engineering majors in college. Yet fewer women than men pursue these majors. Among first-year college students, women are much less likely than men to say that they intend to major in science, technology, engineering, or math (STEM). By graduation, men outnumber women in nearly every science and engineering field, and in some, such as physics, engineering, and computer science, the difference is dramatic, with women earning only 20 percent of bachelor's degrees. Women's representation in science and engineering declines further at the graduate level and yet again in the transition to the workplace (Catherine Hill et al., 2010).

Despite significant improvements in the last couple of years, women are still under-represented in science and technology, both in the academic and private sector. This is due to a variety of reasons, mostly related to the role allocated to women in modern society as well as pre-existing prejudices that form glass ceilings while encouraging male presence in the workplace. It is also however, a result of information or lack of, which places young women in difficult position of making a career choice, with little knowledge of

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available possibilities. Parents, teachers, and career guidance counselors all have a significant role in assisting or hindering the way young women chose their career paths and that choice begins early on from school, all the way through to higher education (Dimitriadi, 2013).

There has been considerable effort in the last decade to increase the participation of women in engineering through various policies. However, there has been little empirical research on gender disparities in engineering which help underpin the effective preparation, co-ordination, and implementation of the science and technology (S&T) policies (Ghiasi. G et.al. , 2015). Among the almost 2000 students who enrolled in challenge-based engineering course in Texas, females constituted a clear minority, comprising only a total of 14% of students. Quantitative analyses of surveys administered at the beginning of the school year 2011 revealed statistically significant gender gaps in personal attitudes towards engineering and perceptions of engineering climate. Specifically, researcher found that compared to males, females reported lower interest in and intrinsic value for engineering, and expressed less confidence in their engineering skills. Additionally, female students felt that the classroom was less inclusive and viewed engineering occupations as less progressive. Gender disparities on all of these measures did not significantly decrease by the end of the school year (C. Riegle-Crumb, C. Moore, 2013**)**. In the current state of STEM higher education, policies aimed at increasing women's involvement focus only on access. Feminist engineering education is a rare component of any engineering education program at universities across the nation. Less than 20% of undergraduates earning a degree in engineering are women, (Elsa Q. Villa et al., 2016).

The pattern of gender participation in technology is similar in Sweden to what has been reported globally. In the early years during which the modern engineering profession and education was developed and institutionalized, women were excluded from participation. However, in Sweden today, it is seen as good for women to become engineers, even necessary. The proportion of women students in engineering has grown from well below 10% in the early 1970s, to about 30% in the late 1990s to early 2000s. Despite the gains in gender equality, however, it is apparent that ambivalence still surrounds `the woman engineer' today. The proportion of women is high in some programmes and very low in others. The career paths of women and men who are engineers are not comparable either. Moreover, a cultural contradiction between being a woman and being an engineer is mirrored in every-day language, where women are depicted as `soft' while technology is described as `hard' (Maria Udeân, 2002).

The purpose of this paper is to evaluate experience of women in engineering education in various countries by reviewing research works which is done by researchers related to experience of women in engineering education in different counties at different time in different direction.

Literature Review

P.D. Schreuders et al. (2009) investigate Pipeline or personal preference: women in engineering. Although the number of women in the engineering field has increased since the 1960s, those increases have largely stagnated over the last few years. . This study examines based on data collected from engineering students attending American universities using an online survey from the fall of 2005 through the spring of 2007. A total of 969 mane and women students from 21 US universities participated in this online survey. This survey used a convenience sample. Data from the survey were exported directly from Survey Suite into an Excel. In Excel, all string data were converted into numerical data for analysis, then enter into SPSS version 14. The finding indicates that, as educators, no need to worry about the willingness of students to learn engineering skills and that the creation of a gender-balanced curriculum for engineering disciplines can be achieved without sacrificing basic engineering skills. Although no significant gender differences emerged in terms of fundamental engineering activities. Their analysis indicated key gender differences in interest in specific engineering activities.

A.E. Smith and B. Dengiz (2010) studied Women in engineering in Turkey – a large scale quantitative and qualitative examination. Data were collected from Middle East Technical University (METU) (Ankara), Bilkent University (Ankara), Gazi University (Ankara), Hacettepe University (Ankara), Bogazici University (Istanbul), Marmara University (Istanbul), and Istanbul Technical University (Istanbul).A total of 671 female students who were attending these universities responded to the survey. The methods include survey and facilitated focus groups. The study shows that women in Turkey choose engineering mainly because they enjoy the underlying mathematics and science. There is no gender bias on the part of teachers or fellow students; however, women students believe that they have fewer opportunities than male peers and acutely feel the lack of role models. Working professionals in industry or government perceive that women assume a more indirect, supporting role; however, women overall strongly affirm their selection of engineering despite some negative factors.

A.Powell et al. (2011) examine a poisoned chalice? Why UK women engineering and technology students may receive more 'help' than their male peers. The UK engineering and technology (E&T) sector is male-dominated, with women facing various cultural and structural barriers in entering and developing their careers within it. This paper explores women's experiences of higher education in engineering and technology, focusing on the gendered help and support women were found to receive, as well as possible causes and consequences of this behaviour. The researcher adopts a qualitative design, using semi-structured interviews with 53 women engineering and technology students' undergraduate degree at a pre- and post-1992 university. Purposive sampling was undertaken of second-year women E&T undergraduates, since students must decide in this year whether or not to undertake the industrial placement. The gendered help women received is shown to be something of a 'poisoned chalice'; although there are sometimes short-term benefits, this is likely to hinder women from progressing in their careers at the same rate as their male peers.

S. Barnard et al. (2012) investigate they're not girly girls': an exploration of quantitative and qualitative data on engineering and gender in higher education. The quantitative data were collected from each country in the sample – UK, Spain, France, Austria,

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Lithuania and Serbia from the year 1972-2008. Through in-depth, semi-structured interviews, in order to uncover engineering students' thoughts and feelings about their educational decisions and experiences in their own words. Interviewers were only from UK in total, 24 interviews with students took place at four universities with 12 female and 12 male students, all within civil engineering departments in 2008. Only students who were in the second, third or final year of their programme were interviewed, as this meant they had more experience to draw on and the questioning would therefore be more fruitful. The interview questions were designed to cover the widest possible range of students' experiences from their decisions to study engineering, their experiences on the programme, reflections on the curriculum taught and gender balance in the staff. The data were analyzed in terms of percentage. The data presented show that, despite some progress in the numbers of women entering engineering programmes, this may be the result of general trends towards increasing numbers of women entering higher education as a whole. European statistics on gender demonstrate a variance between sub-disciplines within engineering and between nations.

Kacey D. Beddoes (2012) examine Feminist Scholarship in Engineering Education: Challenges and Tensions. This article investigate the current state of feminism in the emerging field of engineering education and identifies barriers, challenges, and tensions experienced by scholars and educators who have been involved with feminist engineering education initiatives. Using data from fifteen educator and researchers in-depth interviews conducted through email, in person and Skype selected from US and Australia to show international perspective. The participants worked in several different types of institutions, Snowball sampling was used to select 2 Australian participants and conducted the semi-structured interviews between April 2009 and December 2010. Researcher took a grounded theory approach to analyze the data and identified seven categories of barriers, challenges, and tensions. The categories were: engineering knowledge, culture, and training; engineering education as an emerging research field; publishing; institutional constraints; productive, non-alienating critique and the feminist label; legitimacy and risk; and sustainability.

Singh .S (2013) studied women in engineering education in India**.** The main purpose of the paper was to analyze data on women enrolment as well women faculty members throughout the country. Secondary data from year 1980 – 2005 were used. The researcher concludes that though enrolment in term of number as well as percentage, women participation has increased throughout the country, the growth is not even throughout the country. It varies between states and regions. Though affirmative action as reservation and hostel facility for women students has already been taken, but there is need to expand to enhance scope for affirmative action as fellowship for meritorious students and incentive for women students to join Science, Mathematics and Physics stream at plus two level.

Singh. S, S. Fenton (2014) investigate Women Engineers: A Comparative Study between India and Australia. This study was carryout based on 24 case studies of which fifty –fifty percent case were taken from both countries. Inanition to case studies, researcher used secondary data from the year 1950 – 2011 to investigate trends regarding to participation of women in engineering in the study country. The researcher found that though India and Australia are quite different from each other on so many economic indicators but women participation is low at both places. However, it is important to note that till 1991 it was more or less same but Indian percentage participation has overtaken and also indicates child bearing is the major Couse of attrition. Unless steps are taken to prevent the attrition, there will be a continued loss economically to the country. Researcher inferred that greater responsibility of care work, lake of support system for domestic work within and outside family, male chauvinism among some of the male bosses and opportunity of working part time are some of the reasons for low participation in Australia. While in India, availability of support system, expansion of engineering education system and financial independence at early age are some of the factors which are attracting young girls towards engineering education.

C. García Villa and E.M. González y González (2014) studied Women students in engineering in Mexico: exploring responses to gender differences. The focus of this study was how gender can shape the experiences of female college students in engineering programs. The methodology used in this study was exploratory and descriptive. Participants in this study were female engineering students enrolled in selected colleges of engineering in Mexico at least in third year of collage stay. Twenty respondents from two private and two public universities and from different engineering programs were interviewed. The sample was purposive in design. Ten participants were attending private universities, while the other 10 were students in public universities. Primary data was collected through interview in 2007 and analyzed using the constant comparative method. The percentage of women students in engineering in Mexico is still low compared to the percentage of women enrolled in higher education institutions in the country, which has achieved parity with male enrollment. Findings for this study are presented in two sections. Researcher found the challenges faced by female students in engineering colleges in Mexico, namely, a demanding academic curriculum, and competitive and individualistic environment.

N. Kodate et al. (2014) investigate Paving the way and passing the torch: mentors' motivation and experience of supporting women in optical engineering. This study aims to shed light on both these aspects via the lens of mentors, who are at the coalface of guiding female engineers through their education and subsequent careers. Based on data collected from 25 mentors (8 men and 17 women from 8 countries; USA, Japan, Spain, Mexico, Australia, Canada, Italy and Sweden through interview in August 2011 and October 2013 at the conference held at USA. Data were analyzed using QSR NVivo 9.0 data analysis software. The paper explores their experiences of being mentors, as well as their views on recommended actions for nurturing female engineers. The findings reveal that the primary motivation for becoming a mentor was personal for men and women. Many mentors from countries with relatively lower female labor participation rates perceive their roles as guarantors of their mentees' successful future career paths, and a similar trend can be found in mentors in academia.

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Masako Hosaka (2014) Women's experiences in the engineering laboratory in Japan, This qualitative study aims to examine Japanese women undergraduate engineering students' experiences of interacting with departmental peers of the same year in the laboratory setting by using interview data of 32 final-year students at two modestly selective national universities (Western University and Central University) in Japan. Data were collected through questioner and analyzing by using constant comparative methods. Expectation state theory that explains unequal relationship between men and women is used as a framework. Findings suggest that women generally had a discouraging experience while working with their male peers. Specifically, women participated less and lost confidence by comparing with the men who appeared to be confident and competent.

Makarova et al. (2016) investigate why is the pipeline leaking? Experiences of young women in STEM vocational education and training and their adjustment strategies. The paper investigates the perceptions of young women during their vocational education and training (VET) in traditionally male-dominated science, technology, engineering, and mathematic fields by analyzing mechanisms. Both qualitative and quantitative data were collected from semi-structured interviews from71 young women who had chosen a STEM career and who were enrolled in Vocational education and training in Swiss secondary schools in the year 2012 in German. The interview were conducted through telephone. The interviews were transcribed verbatim, checked for errors and analyzed by using the qualitative content analysis. Thus, data were summarized, segmented and patterned by a category scheme that was deductively determined, but also inductively enlarged according to the empirical material (using MAXQDA 11 software). The main concepts of this approach are categories that are defined elements of analysis. The finding indicate different processes of gendering in Vocational education and training, uncovering various mechanisms and symbolic actions which contribute to the reproduction of a masculine culture in STEM professions. Furthermore, the study provides insight into the different strategies young women apply in order to adjust to gender-atypical educational and professional life domains.

Ong, Smith and KO (2017) Counterspaces for Women of Color in STEM Higher Education: Marginal and Central Spaces for Persistence and Success. This article explores the struggles of women of color that threaten their persistence in STEM education and how those struggles lead them to search out or create counter spaces. Data were collected from purposive sample of 39 women and interviewed about their STEM higher education experience. Using a framework of Critical Race Theory (CRT) and intersectionality theory, researcher found that counterspaces can be physical settings, as well as conceptual and ideological.

J. Bossart, N. Bharti (2017) investigate Women in Engineering: Insight into Why Some Engineering Departments Have More Success in Recruiting and Graduating Women. The purpose of this research was to gain a better understanding of why women preferred certain engineering disciplines over others. From the year 2000-2016 of undergraduate engineering department data from the University of Florida (UF) and national averages from the National Science Foundation (NSF) were reviewed to evaluate graduation rates for women in engineering. Linear regression of the data was used to identify trends. In the last 17 years, there has been little change in the overall percentage of women engineering undergraduates, but there is a great disparity between the engineering disciplines. Women earn larger proportions of undergraduate degrees in engineering disciplines where they perceive a societal benefit.

Conclusion

All reviewed papers about experience of women in engineering education is summarized as follows. Although no significant gender differences emerged in terms of fundamental engineering activities, there is key gender differences in interest in specific engineering activities (P.D. Schreuders et al., 2009). Women in Turkey choose engineering mainly because they enjoy the underlying mathematics and science. There is no gender bias on the part of teachers or fellow students; however, women students believe that they have fewer opportunities than male peers and acutely feel the lack of role models (A.E. Smith and B. Dengiz (2010). The gendered help women received is shown to be something of a 'poisoned chalice'; although there are sometimes short-term benefits, this is likely to hinder women from progressing in their careers at the same rate as their male peers (A.Powell et al. (2011).

Despite some progress in the numbers of women entering engineering programmes, this may be the result of general trends towards increasing numbers of women entering higher education as a whole. European statistics on gender demonstrate a variance between sub-disciplines within engineering and between nations (**S.** Barnard et al. (2012). Seven barriers, challenges, and tensions are engineering knowledge, culture, and training; engineering education as an emerging research field; publishing; institutional constraints; productive, non-alienating critique and the feminist label; legitimacy and risk; and sustainability that affects women in engineering education (Kacey D. Beddoes, 2012). Though enrolment in term of number as well as percentage, women participation has increased throughout the country, the growth is not even throughout the country. It varies between states and regions (Singh .S, 2013).

Women participation is low at both places. However, it is important to note that till 1991 it was more or less same but Indian percentage participation has overtaken and also indicates child bearing is the major Couse of attrition (Singh. S, S. Fenton, 2014). The percentage of women students in engineering in Mexico is still low compared to the percentage of women enrolled in higher education institutions in the country, which has achieved parity with male enrollment (C. García Villa, G, 2014). The primary motivation for becoming a mentor was personal for men and women. Many mentors from countries with relatively lower female labor participation rates perceive their roles as guarantors of their mentees' successful future career paths, and a similar trend can be found in mentors in academia (N. Kodate et al., 2014).

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women apply in order to adjust to gender-atypical educational and professional life domains (Makarova et al., 2016**)**. Researcher found that counterspaces can be physical settings, as well as conceptual and ideological (Ong, Smith and KO, 2017). In the last 17 years, there has been little change in the overall percentage of women engineering undergraduates, but there is a great disparity between the engineering disciplines. Women earn larger proportions of undergraduate degrees in engineering disciplines where they perceive a societal benefit (J. Bossart, N. Bharti, 2017). Generally, this reviewed papers shows that there is underrepresentation of women in engineering education in various parts of the world, even if there is some improvement.

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