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Evaluating challenges faced by female undergraduate students in engineering and the built environment

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Abstract

Female students in engineering programs are still fewer in number in contrast to male counterparts offering same courses after years of professional integration and learning convergence. Currently, in the focal group under exploration, only 28% of students at the faculty of engineering are females, which indicate a wide gap between male and female students within this faculty. The study focus is on identifying challenges which female students experience while studying engineering programs. This is imperative because engineering programs are now less gender selective and it is needful to identify the challenges female students are griping with in order to proffer solutions that will assist the students go through their studies with ease. To identify this problem, a quantitative research approach was taken and data was harnessed from registered female students within the faculty using questionnaires. The results of the study reveals that lack of funding support, inadequate academic mentorship, and peer pressure constitute some of the challenges experienced by female students in engineering faculty. The research outcome is useful as it provides data to guide management in taking informed decision that will address the low intake and number of female student drop out from the engineering faculty.

Keywords
Female students; engineering; study challenges; engineering programs; faculty of engineering

1. Introduction

The society today is engineering and technology based and the quality of life of the people is directly or indirectly related to the quality and level of technical education in vogue. Engineering and Technology are the terms used nowadays in almost all aspects of life from the making of a needle to the manufacture of an space craft. In this progressively shifting world, the human need and services revolve around the engineering and technologies. For the economic and industrial growth of any developing country one of the very important aspects is the progress in the field of engineering and technology. Technical education are playing a major role to the overall education system and also playing a vital role in the social and economic development of the counties. Today's engineering graduates will have to resolve tomorrow's problems in a world that is, as never before, progresses much more rapidly, and facing on its way, new, critical challenges (Madara and Cherotich, 2016). To cater the various aspects of engineering and technological development, social and economic progress technical education is imparted from craftsmanship level, diploma, degree, post graduate degree to research degree in specialized fields. Several publications have

highlighted the significance of recruiting and retention of engineering students, to keep up with workforce demand and technological advancements (Zepke& Leach, 2005; Nerad & Miller, 1996; Yurtseven, 2002; Lau, 2003).

Gender-diversity, in engineering profession and engineering education has been studied by several researchers and the importance has been highlighted in (Starovoytova & Cherotich, 2016). Traditionally, the female-students have been under-represented in the field of engineering and technology. The main-challenges, as acknowledged are based on a remarkable-phenomenon: "when engineering-stereotype and gender-stereotype collide head-to-head" (by Starovoytova & Cherotich 2016). Engineering-stereotype is whereby engineering perceived as "too hard", "masculine" and "noisy and dirty" profession, and Gender-stereotype is whereby females perceived as inferior, feeble, delicate, very dependent, less intellectually and capable, than males species (Madara and Cherotich, 2016).

According to the stereotype, the apt place for the females should be limited to only two-places in the house: kitchen and bedroom. Furthermore, there are also numerous gender-related challenges in learning of technical courses, which additionally contribute to gender underrepresentation in engineering education. As a result, females are driven away from engineering and technology by the content and climate of technical institutions, referred to as an atmosphere of "dominant masculinity" (Livingstone, 2004; Blickenstaff, 2005).

At the he 5th Global Colloquium of University Presidents in April, 2011 The UN Secretary General, in his keynote addressed the titled "Empowering Women to change the world: What Universities and UN can Do". He stated: Women remain second-class-citizens in too-many-countries, deprived of basic-rights or legitimate-opportunities, and he asked participants in the Colloquium fight and overcome discrimination and change perceptions about what women can and should do. Gone are the days when female engineers were masculine, grim women who were constantly exhausting themselves to be considered equal to men. Today's female engineers are passionate, determined, resilient, intellectual and feminine.

1.1 Marginalization of female in engineering education

1.1.1. International perspective

Prior to World War II, women in engineering for practical purposes did not exist in the world. Due to the shortage of engineering talent and at the same time and increasing demand of production of armaments, battleships, the U.S. Office of Education started various of courses in science and engineering that were open to women as the men were recruited into the armed forces during the. During twentieth century, very few women were admitted to science and engineering programs, but were generally looked down by their male counterparts. Various studies at National Science Foundation shows that the percentage of BA/BS degrees in engineering awarded to women in the U.S. has increased gradually from 0.4 percent in 1966 to a peak of 20.9 % in 2002, and then dropped off slightly to 18.5 % in 2008. The percentage of BA/BS degrees in mathematics and computer science awarded to women reached to 39.5% in 1985 since than declined steadily to 25.3 percent in 2008. But the percentage of master's degrees in engineering and science increased progressively from 0.6 % in 1966 to 22.9 percent in 2008. Also the percentage of doctoral degrees in engineering awarded to women has increased from 0.3% in 1966 to 21.5 % in 2008 (Madara and Cherotich, 2016). Currently only 9.6% of women engineers are their Australia are women, and the rate of women in engineering degree courses has remained around 14% since the 1990s (Madara and Cherotich, 2016). In United Kingdom the percentage has progressed from 7 % in 1984 to 15 % in 2007 (Madara and Cherotich, 2016). The proportions of women engineers in industries are still very low at around 6% and the lowest percentage in the EU. Literature on the representation of Women in Science, Technology Math and Engineering (STEM) careers has exposed the manifestation of a "leaky pipeline," (Seymour, 2002) where the women systematically drop out of the STEM-track at various points along the education and career ladder. Hence, institutions of higher learning are under tremendous pressure to improve enrollment and to keep up with educational competence for better student-outcomes, such as retention and completion (Zepke& Leach, 2005). Various quantitative (Duderstadt, 2008; Fleming, 2005) and qualitative (Jackson, 2010; Fouad & Singh, 2011; Bell et. al., 2003) studies have been carried out to understand the processes involved in the undecided approach of women to engineering and at evolving measures to change that situation.

Figure 1 represents the percentage of male and women in engineering in different countries (Engineering and economic growth: a global view, 2016). The maximum numbers of the countries have increased the percentage of

female engineering graduates over the period of four years from 2008-12. The most notable increases are in the emerging economies of Mexico, Hungary and Turkey in these countries, the number of female engineering graduates have increased by over 150%. However, in developed countries such as the United Kingdom and US the increase was often less marked by 31% and 24% respectively.

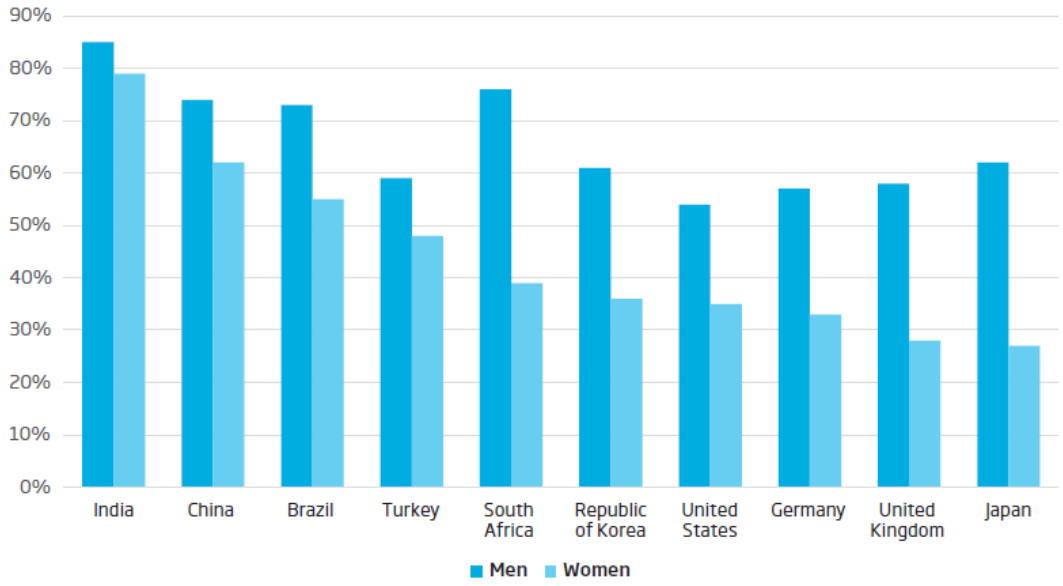


Figure 1: Percentage of male and women in engineering in different countries

1.1.2 South African perspective

To provide the country ranking on the gender gaps, the Gender Gap Index (Hausman, Tyson & Zahidi 2013) scales on the basis of economic, political, education and health criteria. In 2006 in terms of the gender gap index South Africa was the top performer in the sub-Saharan region the country status fell down two positions in 2008 and went out of the top 20. In African countries, Lesotho was ranked 16th in 2008 and took the top position where Mozambique held the 18th position and was the only other African country in the top 20 positions (Hausman, Tyson & Zahidi 2013). Although South Africa ranked 5th among 130 countries with regard to the number of women in ministerial positions, the country took only 93rd position among the 130 countries in terms of economic participation by women and economic opportunities for women (Hausman, Tyson & Zahidi 2013).

Before 1974 no women were reported in engineering in South Africa but after women have progressively begun participating in the engineering profession (Du Toit & Roodt, 2009). In 1996 more than 16.21% professional engineers participating in South African labour market were women. Conversely, figure had declined to only 10.51% in 2005 (Du Toit & Roodt, 2009). The declining trend is not only alarming in the context of the critical shortage of engineering skills in South Africa, but also highlights the continued under-representation of women in engineering.

In 2005, 20.2% of the women have undertaken engineering programs in South Africa compared to 9.4% in 1996. Though the women have constituted about a fifth of the engineering student population, only about 10% of them represent engineering workforce (Du Toit & Roodt, 2009).

1. 2 Female-Challenges in engineering education

The percentages of female graduates in engineering at universities have been increased from 1996–2005, as South African policies and labour laws are rigorously addressing equity and transformation issues by aspiring female engineers: awarding bursaries and various supplementary courses in place and by addressing issues regarding cultural diversity. Black female engineer undergraduates have shown the strongest average annual growth of 23.89%, while the growth of white female engineer undergraduates is only about 4.70%. Over the period from 1996–2005

there was total average annual growth of 10.89% in the number of female engineer undergraduates, it occurred from a small base. Men still constituted the majority of engineer graduates at universities. Figure 2 (a) and (b) represents women vs male engineers in South Africa and women engineers by race.

From 1996–2005 the average annual growth of 24.07% has been seen in the number of black female technologists and technicians. However, the number of graduations of white female technologists and technicians have been declined by –3.51%. Through the interviews in universities and from result analysis it is found that the enrolment and graduation of female engineering students are still lower than enrolment and graduation of male engineering students, but the throughput of female engineering students is higher than that of males. At some of the universities female students have been the on the top positions for up to six consecutive years. Female students are mature and more focused, have better life skills.

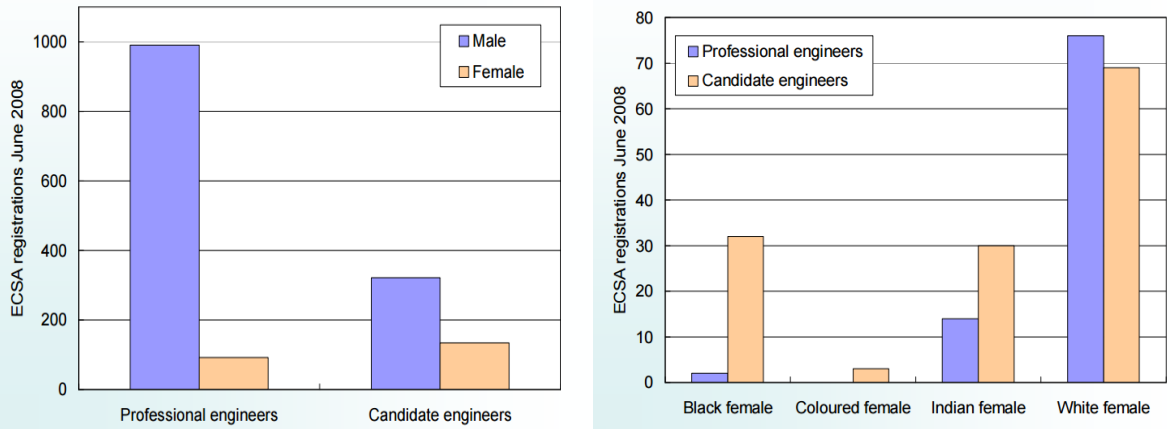
A third of the female students have enrolled in 1996 at universities of technology but in 2005 only 14.4% of the female students who have enrolled for the program. The drop-out rate of women engineering students has many contributory factors. In 1990s campaigns were stated to encourage both historically disadvantaged learners and women to enter engineering studies but without the higher education institutions providing enough information, and without the pre-testing of students suitability for the engineering. As some of historically disadvantaged women students have a poor foundation in mathematics and science and do not have an adequate command of the language of instruction and institutions were not geared to offer supplementary programs theses students feel themselves at disadvantages. Universities should offer special courses to improve students language proficiency and the basics of mathematics and science. Now a days most of the universities offer both foundation programs and psychological support to historically disadvantaged entrants to help them cope with higher education.

Higher education institutions are also failed to address cultural diversity issues as most of staffs in engineering departments remain predominantly white and male, and there are s till not enough female role models in engineering departments at higher education institutions.

With employment equity measures South African engineering sector has evolved to become more gender-balanced. But it is certainly not stable as according to Engineering Council of South Africa said almost 11% of the total number of engineers registered with the council was women, but that professional women engineers totaled only 4%.

A common thread running through our findings is that because of the prevailing mentality, women engineers do not feel valued and good enough as highly as their male counterparts, leading to immense self-doubt. These conditions are not only of the industry, but the country as a whole. The UN's International Labour Organisation has long highlighted the urgent need for countries to address gender discrimination in the scientific and technological fields and to change the traditional attitudes that exist in these sectors, saying that failure to do so constitutes an obstacle to nations' progress.

South Africa's National Research and Development Strategy stated that human resources in science and technology are not being adequately developed and renewed. The strategy proposes a highly targeted methodology towards increasing merit in mathematics and the sciences among black Grade 12 school leavers and young women. To attract young people to sustainable careers in engineering various centers of excellence are being established. Special programs for the promotion of women in science and engineering have also been proposed. One positive outcome of the research and development (R&D) strategy has been the establishment of the SET4Women Reference Group (Science, Engineering and Technology for Women Reference Group, abbreviated to SET4WRG) as part of the National Advisory Council on Innovation. The SET4WRG consists of female stakeholders and representatives of organisations with an interest in the progress of women in SET, and serves to monitor and advise the Department of Science and Technology (DST) on relevant issues.



(a) (b)

Figure 2: (a) Women vs Male Engineers in SA (b) Women Engineers by Race

DST with SET4WRG is working for various gender and race equity policy. The policy framework will guide institutions and will address the issues of SET for women. The European Commission (2006) report states that it is known that female engineers bring diversity to the monocultural engineering workforce and therefore extend the impact of engineering on society.

As women are more social they can work on the social aspects of technology and science and can make a noteworthy contribution to social and environmental issues. The career path of a female engineering professional starts at an early age by as choosing school subjects, enrolling at a training institution, initial entry into the labour market, and progress in the labour market. In the context of the shortage of female engineering skills it is important to understand the internal and external influences that affect women's choices of engineering, and the barriers that serve to prevent female engineering professionals from full participation and success.

2. Materials and methods

This study is based on the account of the female students at the department of Electrical Engineering, Faculty of Engineering and the Built Environment, Tshwane University of Technology (TUT), eMalahleni campus, South Africa. The University has two campuses in which electrical engineering courses are studied, Pretoria and eMalahleni campuses. eMalahleni campus is known to be a disadvantage campus in terms of the quality of students enrolled and available facilities. The department has the greatest number of students in the faculty. Currently, only 28% of students at the faculty of engineering are females of which 15% are in Electrical Engineering. Consequently, 6% of the 15% of the female electrical engineering students are registered in eMalahleni campus. Challenges related to female students in engineering education were conducted using questionnaires distributed to the female students of 2017 academic year. The undergraduate program is made up of Foundation (Extended) Program (FP), Semester 1 (S1), Semester 2 (S2), Semester 3 (S3), Semester 4 (S4) and Bachelor of Technology (BTech) classes. The questionnaires were distributed to all the classes except BTech class. The number of students per class that participated in the survey are, FP = 43, S1 = 18, S2 = 8, S3 = 12 and S4 = 2. Quantitative method of evaluation has been used in the study in which patterns, themes and categories are examined but focus not on replication (Madara and Cherotich, 2016). Our investigations were based on 82 random sampled questionnaires returned by the students. The questions were aimed at collecting information about the family background and how they come about choosing electrical engineering as career. In addition, the tool investigates their learning experiences in a male dominated department, peer pressure and also looked at their financial challenges.

3. Results

Out of the 100 questionnaires sent out, 83 students returned the surveyed – questioners fully completed. The questionnaires were distributed to female students in Extended Foundation Program (43 students), Semester 1 and two classes. The questionnaire was not loaded with too much questions and were made as easy as possible. This is to

allow easy participation by the student so as to get responses from the students as soon as possible, otherwise the students may not respond to the questionnaires. The questions asked and evaluation procedures are as follow:

Q1. How old are you?

Table 1. Age groups of students evaluated

Age group	**15 - 19**	**20 - 24**	**25 - 29**	**30 and above**
Number of students	46	28	8	2
Percentage	55	34	10	2

As evident in Table 1, majority (55%) of the students that participated in the survey are in ages between 15 – 19.

Q2. What is your parents' level of education?

Table 2. Parents' education level

Level of education	**Father**		**Mother**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Primary	10	12	17	21
Matric	21	25	27	32
College	17	20	15	18
University	3	4	13	16
No answer	29	35	09	11
Not applicable	03	4	02	2

Q3. What is your parents' occupation?

Table 1. Name of the table

Occupation	**Father**		**Mother**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Unemployed	12	15	22	27
Employed	22	27	27	33
Self employed	05	6	5	6
Domestic worker/Gardener	2	2	11	13
Not applicable	39	47	16	19
Pensioner	1	1	1	1
Deceased	02	2	1	1

Q4. Parents place of resident

From the responses, 40 parents live in rural area, 38 lives in urban area while 5 students gave no answer.

Q5 Why did you choose engineering profession?

Motivation	**Frequency**	**Percentage**
Passion	12	14
Love challenges	5	6
Interest	20	24
Love working with electricity	10	12
No genuine reason	17	21
No other option	10	12
No response	9	11

Q6 Are you on funding?

There are forty-four (53%) students who indicated that they obtained loan from National Student Financial Aid Scheme (NSFAS). The scheme aim at transforming NSFAS into an efficient and effective provider of financial aid to students from poor and working class families in a sustainable manner that promotes access to, and success in, higher and further education and training, in pursuit of South Africa's national and human resource development goals. Students who study with the loan will have to refund 50% of the loan obtained when they start working after graduation. Majority of students in South Africa depend on this loan for their University education. In 2017, many students struggled to get the loan but few students are opportune to get the loan. In addition, 4 students' indicated that they got bursary from Gauteng City Region Academy to pay for their academic expenses for the year. The remaining students have their fees paid by their family members. The lack of funding is a big challenge for the students and this has resulted in some students withdrawing from school.

Q7 Do you have academic mentor?

Students' responses to this question indicated that most students don't have mentors. From the responses, 66 (80%) of the students have no mentor, 8 (10%) indicated that they have mentors. The remaining students gave no response, which can be interpreted that they do not have mentors.

Q8 Are you being affected by peer pressure?

The responses retrieved from the questionnaires show that 62 (75%) students are not affected by peer pressure, 11 (13%) are influenced by peer pressure while the remaining students gave no response.

4. Conclusion

This study doesn't sketch a detailed and polished portrait creates of the female engineering learning experience but provides a rough sketch, using a variety of research methods and relying on the female students own words for much of the data. Questionnaires related to the challenges faced by female students in engineering education were distributed to the batch of 2017 academic year. Evaluation has been done utilizing quantitate method in which patterns, themes and categories are examined but focus not on replication. Total of 82 random sampled questions were taken. The questions were based on the information about the age, family background, their learning experiences in a male dominated department, peer pressure and their financial challenges

Based on the finidings it is found the maximum numbers of students are between the age group 15-19 only two students were above the age 30. Maximum parents have studied till matric and are employed. It is also found that 40 parents live in rural area and 38 lives in urban area while 5 students gave no answer. Around 53% of the students has obtained loan from National Student Financial Aid Scheme (NSFAS). The remaining students have to pay their fees. The lack of funding is a big challenge for the students and this has resulted in some students withdrawing from school. Based on the findings, it is also found, that the female students, faced numerous gender-related challenges and peer pressure, even of the students have no mentor in academic.

Although currently Tshwane University of Technology (TUT), has 28% of the female students there is still need for much more females in engineering in order to satisfy ever-growing demand for gender-balanced engineering workforce. Diversity of the student body at academic institutions has immediate economic benefits. In an age where many academic institutions compete for enrolments, in particularly in engineering, not drawing on the pool of women, for example, reduces revenue. Equity, however, does not just mean an equal number of women and men; it means equal chances of success and career opportunities and development.

The study, however, attempted to contribute, in its small way, to the knowledge of difficulties of women in engineering education. Women are naturally creative and engineering is creative too, Women bring a much desirable and exceptional zest to engineering and therefore they should be supported, motivated, protected, respected, appreciated, and promoted.

Acknowledgements

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Biography

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