

Assessing Engineering Disciplines with Expected Success for Females in Saudi Arabia

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Background. The Kingdom of Saudi Arabia (KSA) has witnessed over the last few years a number of strategic developments in the higher education sector, particularly with the establishment of around a dozen new public universities, all seeking to be leading institutions in this educationally developing country. There have also lately been a number of official, strategic decisions pushing towards the equality of both males and females in different higher education disciplines. This has, incidentally, encouraged and invited the female sector to thrive towards STEM (Science, Technology, Engineering, and Math) education opportunities, particularly since engineering disciplines are currently almost solely offered to males nationwide.

Purpose. This paper extends a previous study highlighting the importance of introducing engineering education for females in the KSA. The paper examines engineering disciplines where females are most expected to succeed from academic and career perspectives.

Approach. First, the authors compare the presence and numbers of females in engineering education from an international and regional perspective for different engineering disciplines. This is then used to predict a list of engineering disciplines where Saudi females are expected to succeed, as well as discussing expected job market opportunities. Such is analyzed in view of the essential cultural and religious demands and constraints imposed by the deeply conservative Saudi society. In addition, the authors show the suitability of such disciplines in consideration of the superiority of female performance in pre-collegiate (K-12 grade) STEM education in the KSA.

Discussion. The study substantiates that the Saudi culture is currently ready to accept the integration of females into STEM and particularly engineering education. Saudi girls are also shown indeed capable of competing with their male counterparts in engineering education in Saudi Arabia, as well as females in neighboring gulf and Middle-Eastern countries. Females are, furthermore, shown as very capable of entering and competing in the job market as effective engineers.

Conclusion and Recommendations. In view of the challenging Saudi climate and various cultural and religious demands, Saudi females are most likely expected to succeed in engineering disciplines that do not require field-involvement and mixing of genders. However, a systematic, gradual approach is necessary for the successful implementation of such programs. Future recommendations are proposed involving a practical application of this study in the form of a nationally-funded project.

Keywords: education, engineering, females, Saudi Arabia, STEM

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Introduction

Significant changes in higher education have undoubtedly made their way to the Kingdom of Saudi Arabia. Although widely known as a highly conservative, developing country, governed largely by religion and cultural traditions, the kingdom has witnessed in recent years several initiatives pertaining to higher education. This includes the establishment of King Abdullah University for Science and Technology (KAUST), its first mixed-gender university [1]; its first public women-only and the world's largest university for women, Princess Nora bint Abdulrahman University (PNU) [2]; and its first private women-only university, Effat University [3].

In view of these initiatives, this paper serves as an extension of a previous study that highlights the need in the kingdom for the participation of females in engineering higher education [4]. The authors here present and justify engineering specializations where females are expected to be most successful from both academic and career perspectives. First, an overview is presented regarding the involvement of women in engineering higher education and the job market in select countries. This is subsequently followed by an assessment of possible engineering disciplines where females are more likely to succeed in the kingdom. The paper is concluded by highlights of a prospective proposal that may be used to gradually implement these specializations in Saudi higher education.

Females and Engineering

The underrepresentation of women in engineering is not just a problem in Saudi Arabia, but rather a global challenge, even in developed countries, and in both the academic and professional realms. The following section examines data concerning female engineers in a number of select countries, the gender gap in higher education and the engineering workforce, and the causes of retention of women in engineering.

Gender Gap in Engineering Higher Education and Workforce. Based on data gathered from different studies conducted in recent years, Table 1 lists the approximate percentages of women in higher education, both on a general scale and specifically related to engineering. Select nations have been chosen including the USA [5] - [10], Australia [8], [10], India [8], [11], Malaysia [12], [13], and Jordan [12], [14].

The latter two countries (Jordan and Malaysia) are notable in having experienced success stories that are highly regarded especially in the Arab world since, like Saudi Arabia, they represent a Muslim country (Malaysia) and a neighboring Muslim and Arab country (Jordan), where there is a very high literacy rate, for both men and women alike. For example, Malaysia has shown an impressive increase of female students in undergraduate engineering programs, rising steadily from 5% in 1981 to be currently almost equated to that of their male counterparts [12]. However, the numbers clearly demonstrate that although women compete with and, in some cases, supersede their male counterparts in higher education, women in engineering

higher education are generally represented by significantly lower percentages in all the above countries.

Table 2 shows the representation of women in the total workforce, both on a general and an engineering-related basis (in engineering jobs or as registered engineers) in the same countries discussed above, USA [6], [9], [15], Australia [15], [16], India [8], [15], Malaysia [12], [15], and Jordan [12], [15]. As with Table 1, Table 2 portrays that the percentage of females in the engineering workforce is much less than that of men. Furthermore, (in most countries) most female engineering graduates do not seek a career in their field of study due either to unemployment or choosing different career paths. There is a notable exception to the percentage of women in engineering careers in Jordan, which although low (31%), surpasses their representation in the country’s general overall workforce, as well as representing a great rise from an earlier overall national representation for females of only 19% between the years of 1948 to 2011 [12].

Table 1: Percentages for women in higher education (general and engineering) in select nations around the world.

Country	Percentage of females in higher education	Percentage of females in engineering higher education
USA	57%	20%
Australia	55%	14%
India	41%	28%
Malaysia	61%	40%
Jordan	52%	40%

Table 2: Percentages for women in the workforce (general and engineering) in select nations around the world.

Country	Percentage of females in the workforce	Percentage of females in engineering jobs
USA	46%	14%
Australia	46%	10%
India	24%	14%
Malaysia	39%	20%
Jordan	19%	31%

Engineering Disciplines Women Choose Most. Although women are greatly underrepresented in engineering, there is quite a disparity in participation among various engineering disciplines that women pursue. Worldwide, women are more likely to go after the ‘softer’ environmental, chemical, and civil engineering, and are least likely to study the ‘harder’ or more ‘masculine’ mechanical, and aeronautical engineering [17]. Softer engineering refers to

those disciplines that usually require less field work and less exposure to harsher travel, weather, and extended working-hour conditions, all of which are encountered in harder disciplines.

Indeed in the US, of the engineering bachelors' degrees awarded during the 2013-14 academic year (with a net 20% of the degrees awarded to women), the highest women percentages were in environmental (48%), biomedical (41%), chemical (36%), biological and agricultural (34%), and industrial and manufacturing and systems engineering (32%) [18]. Similarly in 2010, Jordan witnessed more women engineers than men in both chemical engineering (by 15%) and architecture (by 11%) [12].

Perhaps it is the fact that the 'masculinity' bias generally attributed to engineering [6] is less profound for the above-mentioned engineering disciplines compared with the 'harder' engineering disciplines, thus creating less deterrence for females. This is, undoubtedly, added to the usual incomplete or improper public perception of the nature of what engineering is or what an engineer does as being not suitable for women [19].

Retention of Women in Engineering. Vincent-Lancrin [10] elaborately explains the reason why there has been a reversal during recent years of gender inequality to the benefit of females in higher education in many countries around the world, and summarizes this as owing to a number of "demographic, economic, sociological and educational factors." For example, women now marry and have children at a later stage of their lives -with the use of contraceptives- than they used to, experience less discrimination at the workplace, pursue higher education according to well-defined economic needs, and perform continually better than males in pre-collegiate education. These results are evidenced by the numbers in the first column of Table 1.

With the rise of female participation in higher education, there are, however, a number of reasons why women either choose not to pursue a higher degree in engineering or a subsequent career in engineering, or leave engineering after a short career. The reasons may slightly differ from one region or culture to another. A recent US research study [20] has mainly attributed such poor participation of females in engineering higher education due to the current dominance of a male problem-solving style along with a low tolerance to the much different, more "disciplined and process-oriented" female problem-solving style.

Although lately in the US there have been positive results from encouraging women to join STEM (science, technology, engineering, and math) education, 40% of women who earn degrees in engineering either quit their jobs or don't even start a career in engineering [5]. A widespread study conducted in 2009 showed that women left engineering jobs mainly due to the negative impact and stress resulting from a non-healthy work environment (e.g. lack of support and undermining by supervisors and co-workers), unclear work roles, improper work incentives (low salary and long work hours), and lack of strong communication among women engineers [7]. The Society of Women Engineers (SWE) reports that 25% of women leave engineering at the age of 30, as compared to 10% for men [5].

In addition to the factors mentioned above, Indian women also leave engineering careers at an early age due to family and children commitments [8]. In Jordan, where although women

represent a majority in STEM education (unlike the US), women largely decide on their enrollment in higher education based on individual interest (e.g. working later as school teachers), societal and cultural factors (such as family acceptance of living alone during the study period), and economic restraints (such as scarcity of positions, as well as salaries, and cost of education) [12]. In addition to the above factors, Jordanian women also experience discrimination in engineering jobs in terms of lower salaries than male counterparts (for similar jobs), and less involvement in upper-scale administrative jobs.

Apart from these problems, engineering is quite a popular discipline in Jordan among women, higher than medicine and law, at a 35% rate among enrollment in women higher education [12]. This is due to a number of cultural and societal reasons, such as requiring fewer years than medicine to complete studies (in order to get married early), the availability of more seats in engineering and a greater variety of disciplines than in medicine (in public universities), and the less need for cross-gender interaction in the job and higher promotion of job-independence (in a highly conservative society) than in law or medicine [12].

Engineering for Women in KSA

Much of what has been discussed regarding women in engineering education (especially that pertaining to Jordan) can be extended to Saudi Arabia. In the next section, the authors highlight and discuss the current limited status of women in engineering higher education and workforce in Saudi Arabia.

Saudi Women in Engineering Education. Although there is a slightly less number of girls in Saudi secondary education (about 48%) [21], [22] as there are boys, females considerably surpass their male counterparts in higher education at about 57% of total enrollment [23], and more than 60% of all university graduates [24]; a number that is expected yet to rise in the future. Unfortunately, a disappointing 0.2% of those women earn a degree in engineering every year [25], with the majority of women earning degrees in education, humanities and arts majors, and social and behavioral studies [25], [26].

The problem is that the vast majority of Saudi universities (both public and private) do not currently offer engineering degrees for women. One exception is Effat University, which was the first institution to offer engineering to women in Saudi Arabia in 2006. Among various other departments, its college of engineering offers a degree in electrical and computer engineering, as well as architecture [27]. KAU (King Abdulaziz University) also witnessed the establishment of the first college of engineering in a Saudi public university to offer an engineering degree for women in 2013, with departments of electrical, computer, and industrial engineering [28]. KAUST, which was established in 2009, is another private institution that offers engineering for both males and females (namely in electrical, chemical and biological, biological and environmental, earth, material, and mechanical engineering) but only on the master's and doctorate levels [29]. PNU is a public female university, yet it does not currently offer any engineering degrees. However, very recently (as the authors were in the process of writing this manuscript) a royal decree was issued (February 6, 2018) to establish a college of engineering at PNU [30].

KFUPM (King Fahd University for Petroleum and Minerals), one of the most reputed public universities in the kingdom, is currently being approached to make available a girls' section in the university, and offer degrees in petroleum and excavation engineering [31]. Indeed many Saudi girls do aspire to become engineers in this field, and many travel to earn such degrees from other countries. Public responses regarding this issue is that the university currently offers studies involving the excavation of petroleum which is a "masculine discipline," that is probably "not suitable" for women, and that it is hoped that such "more suitable" disciplines as industrial management will be offered in the near future.

Women in Saudi Workforce. As with Jordan, the rather impressive participation of Saudi females in higher education is contradicted with their disappointing involvement of only 13% in all private and public positions occupied by nationals, according to recent statistics provided by the Central Department of Statistics and Information (CDSI) [32]. Furthermore, according also to the CDSI, unemployment among females reached 34% in 2013, with a 2% increase from the previous year, and more than five-folds that of males (at 6.2%) [21], [33]. 78% of those unemployed women actually do have university degrees [34]. This has been attributed not due to the lack of jobs (with women currently occupying 460,000 jobs in the public sector and 450,000 in the private sector), but rather the slow pace at which females are entering new fields of work. Most women (87.4%) choose to work in education (as teachers and administrators), mostly dictated by social customs and the necessity of a "female-appropriate" work environment [32], [33], [35], much like what has previously been mentioned in the case of Jordanian women, in the even more conservative Saudi society [35]. Women also commonly work as secretaries and nurses [34].

However, as part of its educational and career reform, the kingdom has recently witnessed a number of active training and human resource initiatives to promote the hiring of women in private sectors [33]. Also, a government incentive program has provided companies with a point-based system, whereby one point is granted for hiring a Saudi male, and two points for hiring a Saudi female. In addition, some Saudi financial institutions have recently allowed men and women to work together in the same office [34]. Typically, segregation of genders is strictly implemented at Saudi schools, universities, and the workplace, with exceptions in such places as hospitals and clinics, and (recently) in hypermarkets and shops selling women products.

With very few women graduating from engineering majors every year (153 of the total 61,800 women graduating in the class of 2011 nationwide) [25], it's no surprise that there are currently very few jobs available for women engineers in Saudi Arabia. Nevertheless, literature not only shows that Saudi women are interested in engineering, but the fact that segregation is enforced in schools can be a reason why women may succeed more in engineering than in the US or the UK [4], [36]. Some women who have recently earned engineering degrees from outside the country via the "Program of the Custodian of the Two Holy Mosques" for foreign scholarships represent the first generation of women engineers to get hired in different private sector engineering jobs and projects. Fresh graduate Saudi women engineers, unnecessarily having any previous career experience, are being allowed for the first time to work side-by-side men on design and implementation projects in Jeddah [37].

Addressing the Gender Gap. AlMunajjed [38] portrays a number of major social, legal, educational, and occupational issues that must be addressed in order to solve Saudi Arabia's severe gaps in women's employment, consequently affecting their educational choices (such as engineering). For example, in addition to the need for segregation at the workplace, there are still huge societal concerns regarding the need for women to balance work and family. Legally, there are still only few laws to protect women against discrimination at the workplace, and women are subject to many cases of financial fraud due to the requirement of having a male representative for their businesses.

From an educational perspective, and as highlighted earlier, there is still a great gap to fill in terms of essential higher education needs for females (especially in STEM education), and empowering them with necessary training and various technical, communication, and problem-solving skills; this has partly resulted in approximately 90% of educational output not being linked to the needs of the job market. Finally, women have been mostly restricted in the workplace to a number of 'female-oriented' fields, with less than 1% of them holding higher-administrative (or sensitive) positions.

Therefore, on Saudi Arabia's road to shifting from a petroleum-based to a knowledge-based economy, major recommendations to promote (on a fundamental level) female involvement in education and the workforce include adapting education (at all levels) to fulfill job market needs. This involves promoting various social, problem-solving, technical, communication, work-related, and training skills. Women should also be made aware from an early stage that they are capable of later participating and competing with men in various fields of work and education, such as in engineering education.

Suggested Integration Methodology

On the gradual path to introducing reforms into the Saudi higher educational system, it is highly recommended that a widespread, systematic survey investigation be conducted to identify the engineering disciplines where women are most expected to succeed. The basis for this study should rely on success stories and experiences in Jordan, Malaysia, and other countries, while keeping in mind fundamental social and religious Saudi values. Given also Saudi's challenging climate, it is recommended (at least initially) that some of the 'softer' disciplines such as chemical, civil, electrical, industrial and systems, environmental, earth, and biological engineering be first adopted in Saudi higher education institutions.

This detailed feasibility survey should be distributed to a large group of high-school students, parents of students, academics, important figures, government officials, companies, school administrators, and college and university officials (especially females). Participants should be asked first if they are in support/non-support of female engineering education, why/why not, and their opinions about introducing each of the 'softer' engineering disciplines mentioned above, as well as other disciplines.

As with a similar study concerning female participation in engineering higher education [39], it is expected that the survey be conducted over a period of around 3 to 4 months. Through a large variety of Likert-scale multiple-choice questions, the questionnaire is expected

to include around 60 to 70 questions, with about 10-15 questions addressing each of the topics addressed above. The survey should be first pilot-tested on a sample group of around 30 students to verify its validity and to accordingly address any deficiencies. It should then be equally distributed –electronically– to a wide variety of each of the above-mentioned stakeholders, with an anticipated 2,500 to 3,000 responses. The responses are expected to greatly assist in generally understanding the type and nature of the engineering disciplines preferred by females in Saudi Arabia.

In parallel to these efforts, interviews should be performed with important decision-makers, including officials at the Ministry of Education and other governmental sectors, educational experts, lady members in the “Shura” (consultative) Council,” renowned academics, etc. in order to determine the methodology, as well as expected economic and educational feasibility, preferred engineering disciplines for women, expected outcome, etc. Societal awareness should also be focused on this issue through various media (private and public) outlets, as well as the internet, and the social media.

Following a thorough analysis of results gathered from these surveys and interviews, a suggested implementation strategy should first involve the evaluation and training of girls interested in pursuing an engineering degree after (or during) high school, such as is currently performed by Saudi Aramco company. This training introduces girls to the basics of engineering, and may be conveniently performed in schools or special centers or universities. It will also help in filtering-out girls who are not truly interested in the field. As in the US, this should probably be followed by requiring students to take admittance exams like the standard SAT in addition to other qualification examination models from international universities.

Subsequently, a pre-collegiate or special female freshman year curriculum should also further assist female students and administrators alike in determining the most suitable engineering discipline. The curriculum should cover general, broad aspects of engineering and will help determine the fields in which females perform best at, which fields they are more enthusiastic about, and/or where they need help the most. Results from this series of surveys, interviews, training, orientation, and pre-collegiate courses should confidently serve as a basis to initiate the first few engineering programs in Saudi higher education.

Conclusions and Future Work

In light of the various cultural, religious, societal, and unemployment aspects surrounding Saudi women mentioned in this paper, and considering neighboring countries that have had successful experiences in engineering higher education for women, it is time for Saudi Arabia to seriously consider the gradual integration of several ‘soft’ engineering disciplines that do not necessarily involve mixing of the genders at the workplace. Additionally, Saudi women have shown adequate proof, through participation and performance figures in schools and higher education (as compared to men), to substantiate their involvement in engineering higher education and the workforce. Future steps should involve initiating a nationally-funded, thorough survey investigation addressing various concerned stakeholders in the Saudi educational environment.

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