

Analysis of Masculinities Across Engineering Disciplines

Diana Starovoytova Madara* Sharon Cherotich
School of Engineering, Moi University P. O. Box 3900, Eldoret, Kenya

Abstract
Engineering has remained one of the most male-dominated professions around the world with male-bias in undergraduate engineering student cohorts is still prominent. Little research has been done comparing differences between, or establishing a trend in, enrolment of female engineering students across different engineering departments/disciplines. On the other hand, a key factor in the low number of students entering engineering may be inaccurate perceptions of the engineering disciplines. In this regard, this study is focused on two issues: (1) to examine the pattern of gender-enrolment across the various engineering disciplines offered, in the period between 2003 and 2014, and (2) to review, highlight and clarify on distinguishing information about each area of engineering specialization present in the 5 departments at School of Engineering. A detailed examination reveals that generally, males dominated the entire disciplines. Distribution of female students in engineering departments is not even (both within the subject period and between the departments), and they are, on average, more greatly represented in some departments than others; in particular, Chemical& Process Engineering was found to be the least 'masculine', while Mechanical& Production Engineering-the most. The question "why the enrolment of females varied from one discipline to another?" was logically raised, but remains unreciprocated, as it was outside the scope of this concise study. Nevertheless, this study made a recommendation for further survey to address the issue.
Keywords: females, engineering disciplines, 'masculine', admission, university.

1. Introduction

Engineering has remained one of the most male dominated professions around the world with male bias in undergraduate engineering student cohorts still evidenced (UN, 2010). As engineering educators attempt to respond to the dynamic technological and global issues associated with 21st century advances, statistical data indicates alarmingly low levels of retention for students majoring in science, technology, engineering, or math (STEM) fields (Palazolo, 2010).

The major findings of the recent study of Starovoytova (2016) at the School of Engineering (SOE), Moi University (MU), Kenya for the period between 2003 and 2014, stated that, while MU total admission is steadily increasing, no explicit trend in total enrolment of SOE was established. Analogous, there is no predetermined paten in female admission for both SOE (13.9% average) and MU (45.4% average), however they both skewed in favour of man. The comparison of female admission trends at SOE with other schools of MU revealed that the persistent underrepresentation of females in engineering is perplexing, particularly when female-representation in other programs of MU has enjoyed superior-improvement over time. Engineering parity ration was found to be 1.68 %, meaning that for every 59 students admitted to MU there was only one student admitted to SOE. Female engineering parity index was found to be 0.0038, meaning that on average for 260 female students admitted to MU only 1(one) female student was admitted to SOE. Total retention withdrawal rate was found to be 30%, while retention rate at SOE was found to be 0.9 (10% drop-outs). The data presented in that study raised serious-questions about the future of Kenya's engineering workforce, as the nation needs extra well-prepared and gender-balanced engineering personnel.

These data, further, underscore the importance of attracting more students to engineering. While the above research was done at the SOE as a whole; all engineering bachelor's degrees, however, are awarded in a specific field (discipline) of engineering. Thus, it is important to have a specific engineering discipline(s) in mind when evaluating engineering schools. It also emerged, that some engineering fields, covered by the study, appear to be `masculine' and others `feminine', meaning that females are more greatly represented in some engineering departments than others. Certain engineering disciplines/areas of specialization attract more women than others, and this seems to be fairly universal (Bryson, 2003). A prominent explanation for women's selective representation across engineering disciplines has been that women prefer majors in which the benefit to society is most clear (SCBSBS, 2009; Zengin-Arslan, 2002; Perkins, 2006).

Little research has been done comparing differences between, or establishing a trend, in enrolment of female engineering students to different departments/disciplines. The study hypnotizes that women are not distributed equally across the engineering disciplines.

On the other hand, one key factor in the low number of students entering engineering majors may be inaccurate perceptions of the engineering disciplines (Streveler et. al., 2008). The 2008 report from the National Academy of Engineering, "Changing the Conversation: Messages for Improving Public Understanding of Engineering", cites the lack of consistent messages regarding engineering as one source of confusion and misperceptions of engineering disciplines (NAE, 2008).

In this regard, this study is focused on two issues: (1) to examine the pattern of gender-enrolment across the various disciplines offered, and (2) to review, highlight and clarify on distinguishing information about each area of engineering specialization present in the 5 departments at SOE.

This paper presents preliminary results and basic analysis of the survey data from a larger gender-related study based on SOE, MU. The study is significant because it adds to the existing body of knowledge that examines low female enrolment in engineering and technology education. Additionally, as a result of the study, the researchers anticipate encouraging gender-equity in engineering and technology education programs across Kenya and abroad, that will attract and retain students of both genders. The primary audiences for this article are those policy makers, legislators, educational leaders, and educational and scientific organizations who work to enhance the preparation and diversity of Kenya's future engineers.

2. Materials and methods

The study was conducted at the SOE, MU, Eldoret, Kenya. MU is the second public university to be established in Kenya, after the University of Nairobi. Main focus of the study is to establish if there are differences among the admission trends across 5 engineering departments at SOE. The departments include: Chemical& Processing Engineering department (CPE), Civil& Structural Engineering department (CVS), Mechanical& Production Engineering department (MPE), Manufacturing, Industrial& Textile Engineering department (MIT), and Electrical& Communication Engineering department (ECE). Data on admissions at SOE was collected per department, enrolment register of SOE, university administrative reports, graduation almanacs and MU Senate records among others were examined throughout the data collection process. The retrospective data was restricted to the period between 2003 and 2014. After weighting the data, the cases with missing values were addressed by using multiple imputations. Missing data provide a source of variation (Sinharay et al., 2001), and providing a single imputation for missing values does not account for this possible variance. Little& Rubin (2002) suggest that multiple imputation provides a more precise estimate of standard errors of parameter estimates. The multivariate normal approach available in STATA 11 to execute the multiple imputation procedure was used. DeAngelo et al. (2011) provide additional details about the multiple imputation procedure. To draw inferences from the collected retrospective primary data, the statistics was coded, summarized, interpreted and analyzed by SPSS software. Thereafter, the data was examined with univariate descriptive statistics. Odds ratios (OR) after adjusting for cohort effect and 95% confidence intervals (CI) are used as indicators of the strength of association. A p-value less than 0.05 is considered as statistically significant throughout the study. Furthermore, the secondary sources of data were utilized to contribute to validation of the findings.

3. Results

The following figures (1-5) show gender-segregated admission statistics (for the subject-period) across 5 engineering departments, SOE, MU. Figure 6 shows the average number of gender-segregated students admitted per department.

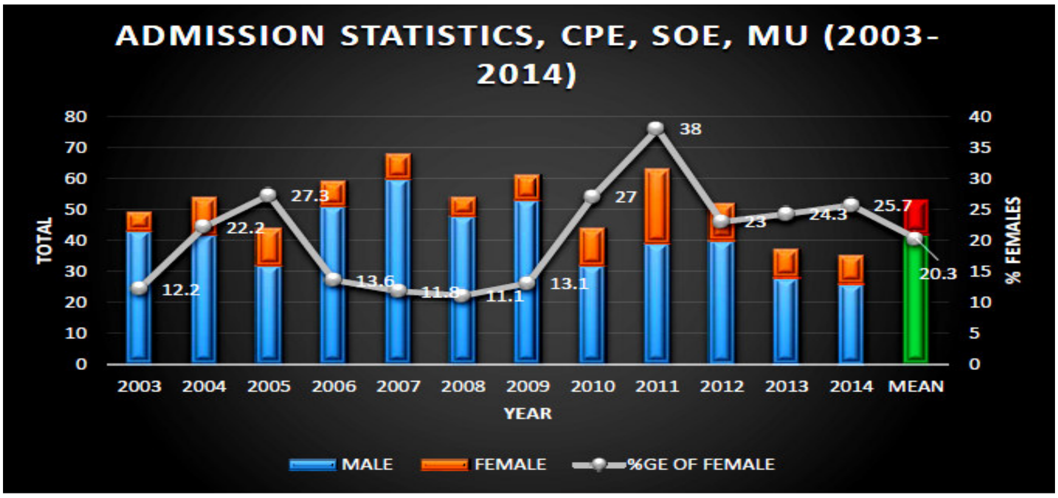

Figure 1: Admission statistics, CPE, SOE, MU (2003-2014)

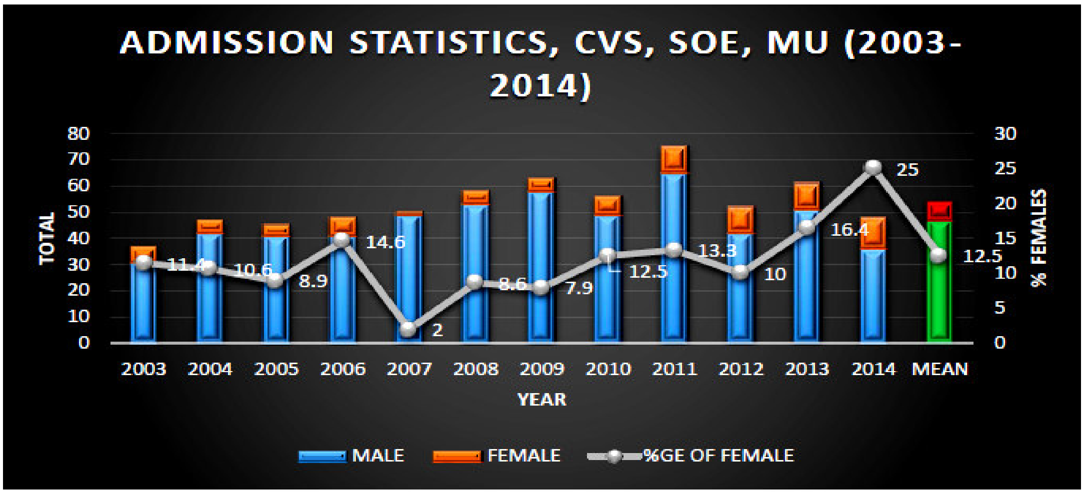

Figure 2: Admission statistics, CVS, SOE, MU (2003-2014)

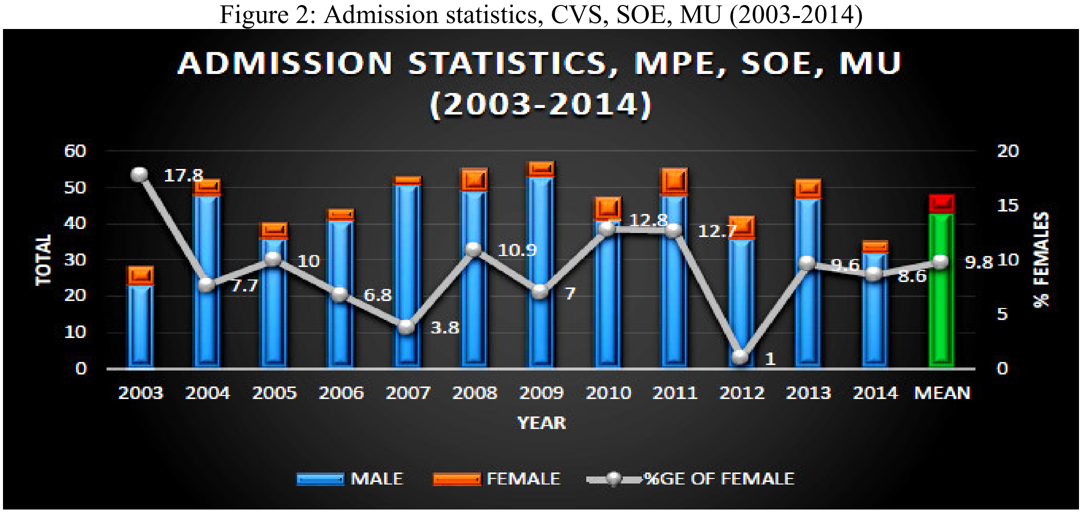

Figure 4: Admission statistics, MPE, SOE, MU (2003-2014)

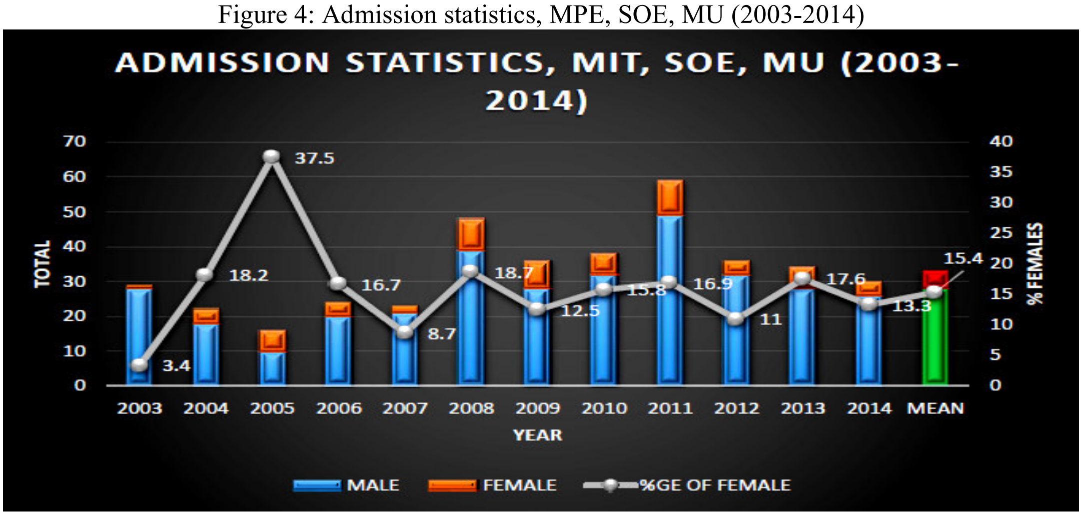

Figure 4: Admission statistics, MIT, SOE, MU (2003-2014)

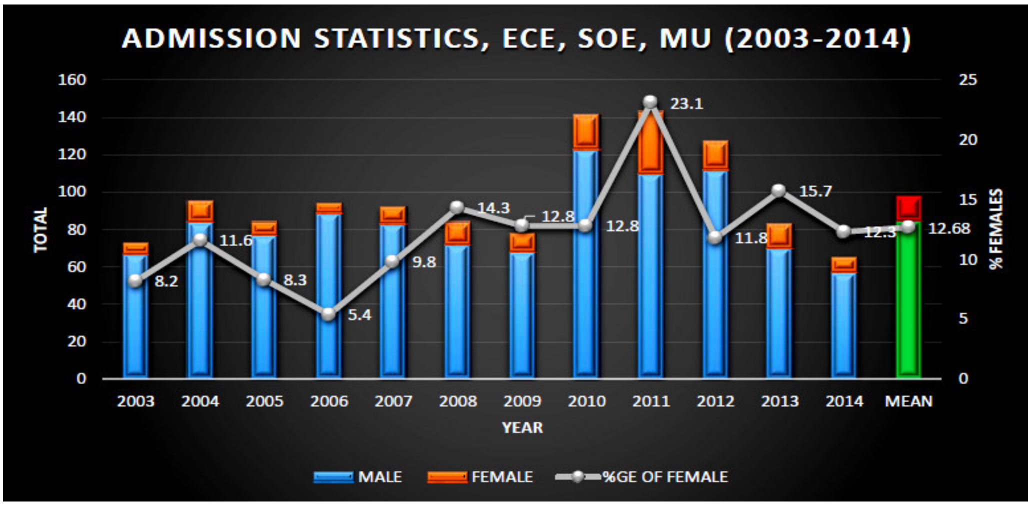

Figure 5: Admission statistics, ECE, SOE, MU (2003-2014)

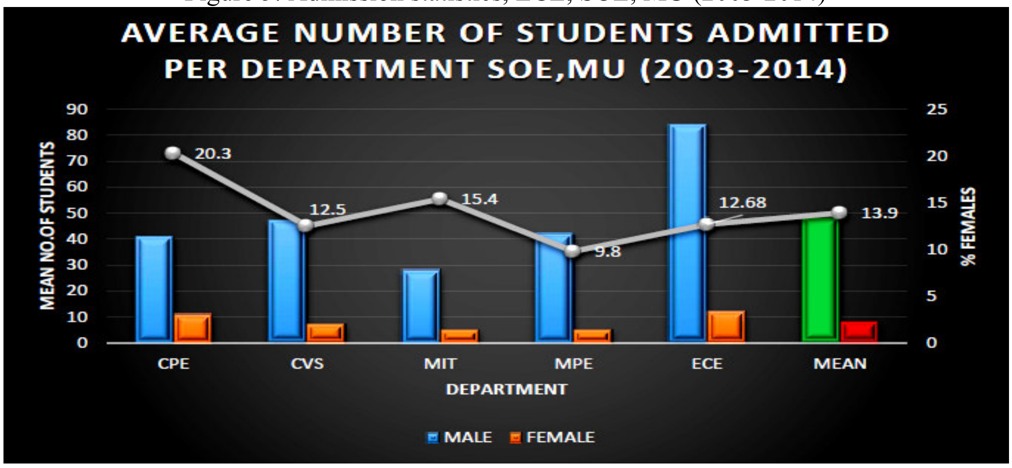

Figure 6: Average number of students admitted per department SOE, MU (2003-2014)

4. Discussions

4.1. Masculinities and femininities across engineering departments

In the *CPE* department, the highest number of females (24) was admitted in 2011. The least number of females admitted was 6 in 2003 and in 2006. The highest percentage of females admitted was 38% in 2011 and the lowest was 11.1% in 2008.

In the *CVS* department, the highest number of females (10) was admitted in 2011. The least number of females admitted was 1 in 2007. The highest percentage of females admitted was 25% in 2014 and the lowest was 2% in 2007.

In the *MPE* department, the highest number of females (7) was admitted in 2011. The least number of females admitted was 2 in 2007. The highest percentage of females admitted was 17.8% in 2003 and the lowest was 1% in 2012.

In the *MIT* department, the highest number of females (10) was admitted in the year 2011. The least number of females admitted was 2 in the year 2007. The highest percentage of females admitted was 37.5% in 2005 and the lowest was 3.4% in 2003.

In the ECE department, the highest number of females (33) was admitted in 2011. The least number of females admitted was 5 in the year 2006. The highest percentage of females admitted was 23.1% in 2011 and the lowest was 5.4% in 2006.

The department with the highest average number of women admitted in the period 2003-2014 is ECE with 13 females, while MIT department had the least average of 5 women being admitted. CPE department had the highest percentage of females, 20.3%, while MPE had the least- 9.8%. The average number of females admitted at SOE is 13.9%.

It should be noted that departments which have approximately 50% female students, have been denoted as `feminine' to emphasize that those departments have the highest percentage of female students. It could be argued that consisting of almost 50% female students are not a satisfactory reason for calling those departments `feminine'; however, their distinctive character should be acknowledged considering that female students have much lower percentages in some other fields of engineering. In this respect, they are relatively feminine'. Describing these departments as `feminine' means that neither that they are naturally suitable for women, nor that women choose them naturally. Nonetheless, the use of `feminine' in quotation marks refers to the constructed character of the identities of these departments as convenient for women. This is also the justification for describing some of the other departments as `masculine'.

From the above analysis, it is clear, that:

1) Males dominate all disciples
2) There is no definite pattern in admission of females and of males.
3) The highest admission of both males and females was in 2011; and it is attributed to double intake, conducted by the Ministry of Education in that year.
4) The admission statistics for females vary, both within the subject-period and between the departments.
5) None of the departments can be put in 'feminine' category, however the departments can be grouped (on the basis of their position with regard to the mean percentage of females admission -13.9%), as follows: (1) Less 'masculine' (admission is above stated mean): CPE and MIT; and (2) More 'masculine' (admission is below stated mean): ECE, CVS, and MPE.
6) CPE is the least masculine, while MPE is the most.

The least masculine department was found to be CPE; this is probably because chemical engineering is thought of as a chemistry department and attracts many women in their decision process. Furthermore, such women assume that chemistry is based on laboratory work and this conception of chemical engineering makes it more likely to be chosen by girls due to its `feminine' qualities of cleanness, meaning that she would rather prefer be a chemist working in a lab rather than an engineer, in its stereotypical understanding.

The `newer' departments, on the other hand, had been established through a separation from the `older' ones: therefore, it can be seen that factors such as the opportunity of finding a job after graduation, the wage level offered by the job, the status it brings and the power of the department in the imagery of the society help to determine the number of women who can enter and which fields they are allowed to participate in. Therefore, it can be observed that females' representation in these relatively `new' engineering departments is higher than in the `older' ones. This is illustrated in our case, with MIT which in itself encompasses 3 distinct engineering disciplines, giving much more opportunity for employment. Technophobia, `the fear or aversion to technology' (Keller, 1992), is another factor that affects women's decision to work in a particular area of engineering. Even though they decided to become an engineer, they tried to choose a field of engineering which is `less' technological than others. MIT' component, Industrial engineering, is viewed as close to the department of management, which is also a department with a high percentage of female students. In this respect, this field is believed to be more `social' than other engineering departments. It can be suggested that women, who want to be engineers but not `technologists' consider industrial engineering as an alternative.

The next thing that draws attention is that the more `masculine' departments are historically the oldest engineering disciplines, like, in our study, Mechanical (MPE) and Civil engineering (CVS). It is true that the oldest engineering fields, mechanical and civil engineering (Mitcham, 1978), which were established in the 19th century during the industrialization period, have the lowest representation of women amongst all engineering fields in all industrialized societies. Women have only recently gained even that low percentage of entry due to changes made in education and training in those fields (Keller, 1992). In cultural imagery `femininity is incompatible with technological competence.'(Cockburn, 1988). Thus, even though they work with technology in their professions, they feel removed from or incompetent in technology. The gendered distribution in the field of engineering is assessed as a concealed form of discrimination. It is also believed that females, normally, possess and use limited bodily strength. However, considering the case of electrical and communication engineering (ECE), which requires mostly lab or office work and intellectual activity, this argument seems contradictory. In other words, despite its cleanliness and `softness', it is still a male dominated field. Here, it is possible to see `men's claim for both manual and mental superiority' (Cockburn, 1988).

The study determined that for the subject-period, on average, females represent only 13.9% at SOE. According to Streveler et. al., (2008) one key factor in the low number of students entering engineering may be inaccurate perceptions of the engineering disciplines. Therefore, second objective of this study was to review, highlight and clarify on distinguishing information about each area of engineering specialization present in the 5 departments at SOE.

4.2. Synopsis on the fundamental essence of relevant areas of engineering specialization

The misconceptions of the true and exact meaning of engineering disciplines (by potential students, by their parents and by the society at large) might lead to ignorant, or, even, erroneous-choices of students' future specialization.

Despite the fact that the term of student misconceptions is widely used in scientific literature, not all researchers agree to define students' prior knowledge as misconceptions. The term misconception has many synonyms. Tomita (2008) summarized synonyms existing in the literature for this term. Primarily referred to as misconceptions (Wandersee et.al., 1994), these conceptions also are called “naive conceptions” (Champagne & Klopfer, 1984), “non-scientific beliefs”, “pre-instructional beliefs” (Chinn & Brewer, 1993), “phenomenological primitives or p-prims” (Goris, 2010), “intuitive knowledge” (Vosniadou et.al., 2001), “alternative frameworks” (Carey et.al., 1989) or “facets” (Minstrell, 1992). “Regardless of terminology, the point is to recognize that a students’ prior-knowledge is embedded in a system of logic and justification, although one that may be incompatible with accepted-scientific-understanding” (Tomita, 2008). The issue of students’ misconceptions crosses multiple-disciplines in science, cognitive-psychology, pedagogy, technology and engineering-education.

In this-regard, to bring some-light and to update-readers, the following is an epigrammatic-summary of concepts and the essence of the engineering areas of specialization, offered at the departments of SOE. The authors believe that this summary is reasonably-accurate, as well as potentially-helpful for researchers, educators in these-disciplines, as well as career-chancellors at high-school-level and potential-engineering students and their-parents.

4.2.1. Department of Chemical & Process Engineering (CPE)

This department combines two engineering disciplines: *Chemical Engineering*, which involves the changing of raw materials into products by the application of the principles of science and engineering; and *Process Engineering*, which involves the planning, design and development of activities and operations intended to convert material from one state to another in order to improve its usefulness or value.

Overall Focus of the discipline: Chemical-based manufacturing - applying chemistry for commercial quantity production of a wide variety of products, including: Fuels (gasoline, natural gas); Petro-Chemicals (chemicals obtained from petroleum or natural gas); Agricultural Chemicals (fertilizers, pesticides); Industrial Chemicals (acids, alkalis, organics, salts); Plastics, Polymers and Fibers; Paper and Paper Products; Pharmaceuticals and Drugs; Consumer Products (paints, soaps, household cleaners, etc.); Food Additives/Products; and Advanced Materials (ceramics, electronic materials, composites, etc.)

Chemical engineering usually involves preparing feed materials to an appropriate condition, enabling a reaction or reactions to occur, separating and purifying the products possibly by distillation or like process, controlling wastes and ultimately adding value to a raw material in the production of something useful to people. Chemical Engineers are also involved in the design construction and operation of large industrial plants to mass produce products.

Today, chemical engineers have broadened their occupational horizons to encompass, in addition to traditional chemical and petroleum industries, the metallurgical and mineral industries, manufacturing industries, pharmaceutical and food industries, computer and electronic industries, among others.

Primary Areas of Specialization are:

1) Biotechnology (including for agricultural, food, medical, and industrial applications).
2) Environmental Engineering.
3) Petroleum and Natural Gas (refine crude oil and natural gas).
4) Polymers (focusing on the production of polymeric materials - plastics, synthetic rubbers and fibers, films and composite materials).
5) Process Control Systems (for managing and optimizing the operation of large-scale, chemical-based industrial operations).

4.2.2. Department of Civil& Structural Engineering (CVS)

This department combines two engineering disciplines: *Civil Engineering*, which involves the planning, design, construction and maintenance of structures such as roads, railways, airports, docks, and tunnels; and *Structural Engineering*, which involves the planning, analysis and design of the elements of structures such as buildings, bridges and silos, so as to be able to resist predetermined loads and forces.

Overall Focus: “Public works”/infrastructure and buildings/structures.

Primary Areas of Specialization are:

1) Construction Management (combining engineering and management skills to complete construction projects designed by other engineers and architects).
2) Environmental Engineering
3) Geotechnical Engineering (analysis of soils and rock in support of engineering projects/applications - building foundations, earthen structures, underground facilities, dams, tunnels, roads, etc)
4) Structural Engineering (design of all types of stationary structures - buildings, bridges, dams, etc.)
5) Surveying (measure/map the earth’s surface in support of engineering design and construction projects and for legal purposes - locating property lines, etc.)
6) Transportation Engineering (design of all types of transportation facilities/systems – streets/highways, airports, railroads, other mass transit, harbors/ports, etc.).
7) Water Resources Engineering (control and use of water, focusing on flood control, irrigation, raw water supply, and hydroelectric power applications)

4.2.3. Department of Electrical& Communication Engineering (ECE)
ECE Department combines two engineering disciplines: *Electrical engineering*, which specializes in different areas such as power generation, transmission, and distribution; communications; and electrical equipment manufacturing, they also test equipment, solve operating problems, and estimate the time and cost of engineering projects; and *Communication Engineering*, which solves problems related to communications, such as radio, television, and telephones; Create ways to use renewable energy – wind, solar and water power instead of gasoline and coal; Collaborate with biomedical engineers to make hearing aids and prosthetic arms and legs which can move - for people who are missing these abilities from accidents or birth defects
Overall Focus: All things electrical/electronic – electronic devices, electrical systems, electrical energy, etc.
Primary Areas of Specialization are:
1) Communications (transmission and processing of information via various means - wires, cable, fiber optics, radio, satellite, etc.)
2) Computer Engineering
3) Digital Systems (digital-based communication and control systems)
4) Electric Power (generation, transmission, and distribution of electric power)
5) Electronics (electronic devices and electrical circuits for producing, detecting, and controlling electrical signals for a wide variety of applications)
6) Robotics and Control Systems (machines and systems that perform/control automated processes)

4.2.4. Department of Manufacturing, Industrial & Textile Engineering (MIT)
MIT combines three engineering disciplines: *Manufacturing Engineering*, which organizes ways of transforming materials and devices into products - from machinery, food processing, pharmaceuticals, computers, electronics, toys, textiles, chemical products to health, medical, automotive and aircraft production; *Industrial Engineering*, which involves the development and implementation of plans to maximize the efficiency and effectiveness of an organization by examination of how people, machines, energy, resources and information are used to accomplish management's goals and devise ways to improve those methods; and *Textile Engineering*, which involves application of scientific and engineering principles to the design and control of all aspects of fibre, textile, and apparel processes, products and machinery.

Most of today's manufacturing engineers and technicians work in high-tech, computerized environments filled with exciting and challenging opportunities. Graduates could be responsible for equipment design, factory layout, parts design, tool design, cost estimating, quality control and robotics. Most industrial engineers, as the name implies, work in industrial set-ups of different magnitude. Textile engineers work in textile manufacturing industries, textile factories, and in textile design companies, among others.

Overall Focus: Efficiency, or, more precisely, how to design, organize, implement, and operate the basic factors of production (materials, equipment, people, information, and energy) in the most efficient manner possible. The typical focus is on optimizing industrial manufacturing operations, although the skills learned can be applied to other non-manufacturing settings.
Primary Areas of Specialization are:
1) Ergonomics / Human Factors Engineering (designing the workplace to better accommodate “human factors” (human abilities and behaviors), thereby yielding more efficient operations and fewer accidents or injuries).
2) Facility Design (aimed at operational efficiency)
3) Management Decision Making / Operations Research (using statistics and other forms of data analysis to aid in making management decisions)
4) Manufacturing Engineering (concerned with all aspects of manufacturing operations – materials, parts, equipment, facilities, labor, finished products, delivery, etc.).
5) Quality Control (using sampling, statistical analysis and other techniques to assess and maintain the quality of products or services provided by a business or other organization)
6) Work Design (defining jobs that individual workers do in performing the overall work of the organization, with the typical focus being on optimizing manufacturing operations).
7) Worker Productivity (conducting time and motion studies, setting work performance standards, and proposing new/improved work methods)
8) Textile engineering, textile technology and textile manufacturing

4.2.5. Department of Manufacturing& Production Engineering (MPE)
MPE combines two engineering disciples: *Mechanical engineering*, in which engineers research, develop, design, manufacture, and test tools, engines, machines, and other mechanical devices. It involves design all types of machines that produce or use power (like jet engines, steam engines, power plants, underwater structures, tractors for food production, hydraulic systems, and transportation systems). They work on power-producing machines such as electric generators, internal combustion engines, and steam and gas turbines. They also develop power-using machines such as refrigeration and air conditioning equipment, machine tools, material

handling systems, elevators and escalators, industrial production equipment, and robots used in manufacturing. Mechanical engineers also design tools needed by other engineers for their work; and *Production Engineering*, which is a combination of manufacturing technology with management science. It encompasses the application of casting, machining, joining processes, metal cutting, tool design, and automation among others.

Overall Focus: Machines, structures, devices, mechanical systems, and energy conversion systems.

Note: Mechanical Engineering is often considered the oldest and the broadest of engineering disciplines, with overlap into many of the other existing engineering disciplines, including Civil, Electrical, and Chemical Engineering.

Primary Areas of Specialization are:

1) Solid Mechanics (analyzing the behavior of solid bodies subjected to external loads, stress, and/or vibrations and using that information in the design and manufacture/construction of such bodies)
2) Fluid Mechanics (analyzing the behavior of liquids and gases and using that knowledge in the design and development of machinery and systems that can and/or do influence that behavior – pumps, fans, turbines, piping systems, etc.)
3) Thermodynamics (analyzing the conversion one form of energy into another and using that knowledge to design and develop energy conversion devices and systems – power plants, engines, Heating, Ventilation, and Air Conditioning (HVAC) systems, etc.)
4) Mechanical Design (covering the full range of mechanical-based products and systems)

5. Conclusion and recommendations.

The article analyzed the trend and pattern of gender enrolment across the 5 departments at SOE, MU. A detailed examination reveals that generally, the males dominated the entire disciplines. Distribution of female students in engineering departments is not even (both within the subject-time-period and between the departments), and they are, on average, more greatly represented in some departments than others.

Why the enrolment of females varied from one discipline to another is still remains unreciprocated (as it was outside the scope of this concise-study). In an effort to determine factors that may influence students' selection of engineering-disciplines at the SOE and to address why female students give preference to some areas of engineering specialization and not to others, this study recommends to survey and examine how entering engineering-students view the various-fields of engineering that are available at the SOE. The survey should include, but not limited to, the following parts: Level of academic difficulty, Availability of career opportunities in the country; Impact of engineering discipline on society; Importance of current technology in particular discipline; Importance of creativity and imagination; and, Associated professional responsibility among others.

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