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Female Students and the Field of Engineering: Stemming the Tide of Gender Underrepresentation for Sustainable Development

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Abstract

Underrepresentation of females in the field of engineering is overwhelming and posing a serious concern to the human race, especially in the developing countries. This has grievous impacts on the socio-economic and environmental growth and development of the nation. The paper seeks to investigate: i) female students' knowledge of the fields of engineering; ii) female students' perceptions of what the gender of engineers ought to be; and iii) the various factors that influence students' career choice in engineering. The study was a descriptive study of the survey type. Data were collected using a self-constructed questionnaire. The sample of the study was 366 public female senior secondary II students who were in science class in Ikere-Ekiti, Nigeria. The findings revealed that majority of the respondents were familiar with the traditional disciplines in the field of engineering. The respondents perceived engineering as a male-dominating profession. Personal, family, school, and social indices were adduced as factors responsible for female students' choice of career. It was concluded that there exists gender discrimination in the choice of female students' career. It was recommended that female students have the ability, rights, knowledge, and duties in the society, and they can be professionals in engineering.

Introduction

Researching the present paper titled "Female Students' Career Choice in Engineering: Stemming the Tide of Female Gender Underrepresentation" is driven by the researchers' curiosity to know the reasons why female folk appears to be sidelined in ground breaking innovations and development in engineering unlike the fields of arts/humanities in the third world countries. There are several laudable achievements and giant strides actualized by female folk in the arts and humanities, but such cannot be said of engineering and technology in Nigeria. Therefore, this study seeks to probe into female students' passion, curiosities, engagement, dreams, fears, and drawbacks at making career choice in the fields of engineering. Engineering has become a cynosure as a field of study. It is a field that combines different school subjects like Physics, Chemistry and Mathematics, including technology. Engineering aims at improving the society, boosting the economy of the nation, providing different lucrative job opportunities, and improving the living conditions of the citizenry by designing, constructing and manufacturing different products based on the needs and expectations of the nation (Cullen, 2019). Engineering is of different major divisions with other numerous subdivisions. The first is mechanical engineering which

focuses on designing, building, and fixing mechanical systems, such as engines, tools, or machines. It involves designing of power generation equipment, medical equipment, robots, automobiles, aircraft, heating and cooling systems etc. Its close divisions are *aerospace, marine, and automotive engineering. The second is electrical engineering which centers on power generating and distribution and using it to control* machines and devices. It is also about the use of electricity, electronics, and electromagnetism. Other subdivisions of *electrical engineering **are** telecommunication **and** computer (hardware) engineering* **(**Ciubotaru, 2023).

The third is civil engineering which specializes on designing and building infrastructures like buildings, bridges, roads, airports, the sewage system, and sewage treatment plants, water supply systems and dams. Its close divisions are structural, environmental, and transportation engineering. The fourth is chemical engineering which is about using chemical processes to transform raw materials into finished products. Its close divisions are *pharmaceutical**,** biochemical, and textile engineering*. The fifth is industrial engineering which focuses on maximizing complicated systems and processes in commerce, services, healthcare, transportation, and manufacturing industries. Its close divisions are *systems**,** supply chain**, and** manufacturing engineering. Other divisions of engineering are* software, mechatronics, agricultural, biomedical, materials, nuclear, petroleum, and mining and geological engineering (Ciubotaru, 2023).However, in spite of the significant contributions of engineering to human existence, deliberate and painstaking look into the society shows that there is a wide gap in the number of male and female engineers in the society. Underrepresentation of females in engineering is overwhelming and posing a serious concern to the human race. To confirm this observation, Leevers (2023) noted that from early childhood, there has been gender disparity in young girls' interest in engineering compared to boys where 42% of girls considered engineering as a suitable career.

Gender is explained to be a set of pre-conceived characteristics, potentials, expectations, and attitude about being feminine and masculine which is determined from biologically traits – also known as "sex." (Rolleri, 2013). UNICEF (2017) defined gender as a socio-cultural construct which differentiates distinctions in the features of being male or female (boys and girls, men and women) and attributes these features to the roles and responsibilities of being men and women. In some traditions, norms, behaviour, habits and practices are endemic and are generally regarded as suitable for individuals of a particular sex. These socio-cultural norms, as a rule, dictate responsibilities, work, tasks, and obligations assigned to individuals on the basis of being a boy, girl, man and woman. Gender-based tasks are often modified by household structure, access to resources, specific impacts of the global economy, occurrence of conflict or disaster, and other locally relevant factors such as ecological conditions (UNICEF, 2017).

Ramachandran et al. (2020) noted that gender gap persists among the various fields of study in Science, Technology, Engineering and Mathematics (STEM) disciplines, however, engineering is the worst hit and has continued to witness highest rates of attrition (40%). Excell (2011) affirmed that even in the United Kingdom, according to the Institution of Engineering and Technology's (IET) annual workforce survey, efforts have been geared to encourage women, yet the progress recorded appears to have stalled. The UK have 8.7% of female engineering professionals in the European Union but the IET points to decline in the number of female engineering technicians from 5% to 3% since 2008. Start (2016) in Ramachandran et al. (2020) observed that on average, less

than 10% of engineers worldwide are females. Marsden (2021) asserted that at every stage of the education system, more boys study STEM subjects than girls because unconscious, but implicit bias still remains, and many people still associate scientific and mathematic fields as 'male' and the arts and humanities as 'female.'

Some of the reasons raised for low proportion of female enrolment rate in engineering include: lack of female engineering role models; individual attitudes to STEM-related subjects; self-efficacy; social networks and support systems; rules; regulations; gender stereotypes and norms that define traditionally "feminine" or "masculine" professions; misconceptions of the roles of an engineer; lack of confidence; external validation; differences in biological characteristics (brain structure); peer effect; individual preferences and beliefs; and inability to provide solutions to technical-related problems from kindergarten to secondary education compared to males (Cullen, 2019; Ramachandran et al., 2020; Marsden 2021; Agurto et al., 2021). Fox-Turnbull et al. (2023) noted that factors responsible for female's repugnance or preference for engineering are multidimensional and range from economic, political and cultural influence down to family, peer pressure and personal factors like self-efficacy.

Agurto et al. (2021) asserted that the popular negative gender stereotypes and beliefs about women's biological ability fit for engineering fields have endangered female paths in career choices. Women are assumed to suit careers in the humanities or the social sciences but not good at maths. On the contrary, men are believed to be naturally proficient at math. Therefore, to excel at engineering, is assumed simple for men. However, women are demotivated by cultural and religious stereotypes and assumptions to choose careers accordingly to their actual talents and abilities. The low number of women in engineering has dire consequences on economic growth and development. Consequently, women will have little or no input in the development of new ideas in science, technology, creativity and productivity (Agurto et al., 2021).Gender stereotype reflects socio-cultural impression and beliefs about females and males. Gender stereotype emanates from gender roles which delineates the responsibilities of females and males. Gender stereotype is categorized into four patterns which are in form of traits, physical characterization, behaviour and occupations (Kimaro & Lawuo, 2016). Gender stereotypes affect self-perception, attitudes and influence participation. In a school setting, gender stereotype can determine learner's classroom experience, academic performance, subject choice and well-being. Individual students in the classroom differ in the extent to which they derive their goals from internal and external factors of learning. Intrinsic factors to study a course originates from within to achieve personal satisfaction, acquire knowledge or possess ability to carry out a task such as students' knowledge, individual preferences and self-efficacy. Extrinsic factors to study a course stem from outside. These factors are external drivers that propel learners to achieve personal satisfaction, acquire knowledge or possess ability to carry out a task such as female role models, peer effect, locality, teacher-factor, and parents' educational status (Elrod & Cox, 2006; Camacho & Cordova-Wentling, 2006; Dasgupta & Stout, 2014; Alawi & Al Mubarak, 2019). Kimaro and Lawuo (2016) affirmed that cultural beliefs on gender roles has been one of the factors that affect correct choice of career path for many secondary school students.

Onyekwere et al. (2018) recorded that there is gender difference on the variable of extrinsic and intrinsic motivation on academic performance, that is, female were intrinsically motivated than males, while males were more extrinsically motivated than females. Shah et al. (2020) noted that increase in parental education ultimately affects the students' science achievement, and the higher the level of parental education, the higher the science

achievement of students would be. In the study of Agurto et al. (2021), it was reported that only 8% of the female student population picked engineering related fields of study. This low enrollment has grievous impact on the society, economic growth and development, and women in particular because they will have little or no input in the development of new ideas in science, technology, creativity and productivity. Leevers (2023) observed that there's a gender imbalance in the way young people think about engineering which we can try and improve by changing the ways we talk to young girls about engineering and tech careers.

Objectives of the Study

Many female secondary students who are in science class appear not to have valid information about career opportunities in the fields of engineering. This has swayed some feeble-minded female students from studying course of choice. Stereotypes devaluate status, social class and value of an affected individuals. These affect their rights, duties, competence, and position in the society reducing them to a particular attribute or disposition that either demeans them or confines them to achievement only in association with this attribute or disposition (Pickering, 2015).

This paper tries to transform the mind of female gender, reshape their self-perception, and influence their involvement in the fields of engineering. Ramachandran et al. (2020) posited that countries like Singapore, India, Sri Lanka, Tunisia, Mozambique, and Turkey have recorded a huge number of female in the STEM fields. Therefore, there is the need to come up with effective strategies that could help Africa female folk see their potentials in the fields of engineering, tap into the potentials and, in the future, contribute their quota as seasoned engineers. Some studies carried out outside the shores of Africa (Elrod & Cox, 2006; Camacho & Cordova-Wentling, 2006; Dasgupta & Stout, 2014; Alawi & Al Mubarak, 2019) have investigated reasons why females shy away from the field of engineering. Findings from these studies showed that that exist gender stereotypes in career choice in engineering, but different factors were considered as responsible for the discrimination.

This present study therefore seeks to domesticate these studies in Nigeria as an African continent to confirm the various factors that are responsible for female science students' career choice in engineering in Ekiti State, Nigeria. The study is guided by the following research questions:

1) What is the level of female students' knowledge of the fields of engineering in Ekiti State?
2) What perceptions do female students have about the gender of engineers in Ekiti State?
3) What are the various factors that influence female students' career choice in the fields of engineering in Ekiti State?

Methodology

Research Design

The study was a descriptive research of the survey type that employed quantitative method of data gathering. Descriptive research of the survey type was employed because the study focused on gathering information on the existing situation and describe the phenomenon as given by the respondents.

Sample and Sampling Techniques

Through random sampling technique, a total of 366 female SSS II who were in selected science class in public senior secondary schools in Ikere-Ekiti, Nigeria were participated in the study. Public schools are government-owned schools. Science class are made up of students who are taught Physics, Chemistry, Mathematics, and Biology. Purposive sampling was used to select the female students as participants. Also, with the use of purposive sampling technique, SSS II students were used as participants because they have gained enough mastery of the subjects to give meaningful results. SSS III are disqualified because they are preparing for their external examinations, and the school management would not want them disturbed while SSS I are new entrants, and have not gained enough mastery of the subjects to give meaningful information. The age range of the respondents was 14-16 years.

Research Instruments and Procedure

The research instrument for the study was a self-developed questionnaire titled: "Female Students' Career Choice in Engineering". The questionnaire was divided into two parts. Part A focused on the demographic information of the respondents. Part B was categorized into Group A, B and C. Group A, with 17 items, focused on the level of female students' knowledge of the fields of engineering in Ekiti State. Group B, with 3 items, addressed female students' perception of the gender of engineers in Ekiti State. With 21 items, Group C examined the various factors (personal, school, family, and society) that influence female students' career choice in the fields of engineering. All the groups were measured using a "Yes or No" format.

Validity of the Instruments

The face and content validity of the instrument was carried out by experts in the Department of Tests and Measurement, Department of Educational Psychology, Faculty of Engineering, and Department of Language Education. After thorough scrutiny of the instruments, corrections were effected before the instruments were adjudged valid for the study.

Reliability of the Instruments

Twenty students each were selected from five secondary schools which were not part of the study. Questionnaire were distributed to a group of 100 students. The reliability of the instrument was tested using Test-retest reliability method. The score was analyzed using Product Moment Correlation statistical tool and the reliability co-efficient of 0.81 was obtained.

Data Analysis

The data collected were analyzed using descriptive statistics of frequency, percentages and bar charts.

Results and Discussion

What is the Level of Female Students' Knowledge of the Fields of Engineering?

Findings from the study (Figure 1) show that the respondents have limited knowledge of the various disciplines in engineering. Out of 366 respondents, 336 respondents indicated that they have the knowledge of chemical engineering, computer engineering (363), civil engineering (300), electrical engineering (350), mechanical engineering (352), and agricultural engineering (121). However, the other engineering disciplines (aerospace, structural, structural, environmental, petroleum, mining, nuclear, robotics, industrial, and geological) appear new to them. Their knowledge of the familiar disciplines is as a result of the long time existence of these areas in engineering unlike the unfamiliar areas which are not studied in some of the higher institutions around the respondents.

The findings are in tandem with the study of Elrod and Cox 2006) that students are familiar with conventional engineering areas like mechanical, aerospace, electrical, civil, chemical, architectural, and computer, but students were unfamiliar with other engineering disciplines related to materials science. Contrarily, in the study of Kimaro and Lawuo (2016), gender stereotyping did not influence career choice on students who had adequate knowledge of their choice and ability in various careers. Hirsch et al. (2003) elucidated that some students have positive attitude to engineering and are considering studying engineering, despite that these students know little about engineering careers and what engineers do.

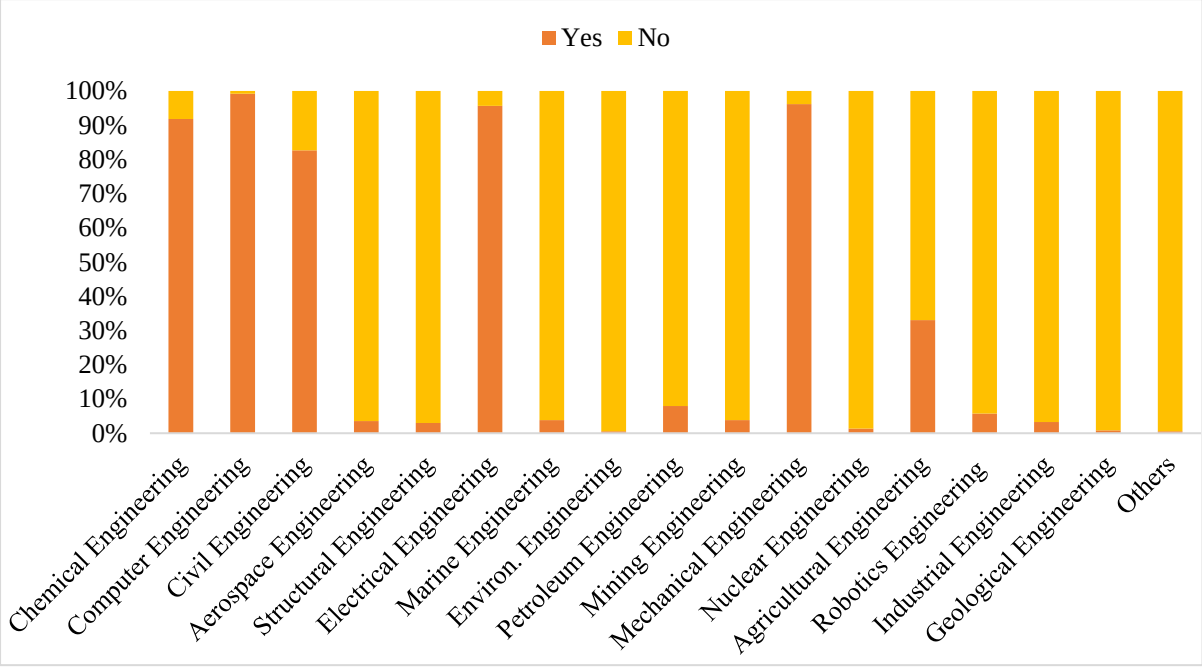

Figure 1. Female Students' Knowledge of the Fields of Engineering

What Perceptions Do Female Students Have About the Gender of Engineers?

Figure 2 reveals that the respondents (320) in the study opined that the disciplines in engineering are most suitable

for male, a large number (308) noted that disciplines in engineering are not meant for female, while a few number (60) affirmed that disciplines in engineering are best suited for both female and male. The findings indicate that the majority of students perceived the gender of engineers as male. The findings are corroborated in a study conducted by Ergün and Balçın (2018), where a few number of participants (12.96%) perceived engineers' gender as female and 87.04% of the students perceived engineers' gender as male.

Also, Agurto et al. (2021) confirmed that popular negative stereotypes and beliefs about women's biological ability fit for engineering fields have endangered female paths in career choices. Their study revealed that women are assumed fit for fields in the humanities or the social sciences were subjects offered are assumed to be simple, feminine and do not need agility, but not to be good at math. On the other hand, male are assumed to be naturally good at math, and historically engineering has been labelled as a male dominant field. These stereotypes and assumptions have conditioned and demotivate the minds of the female folks. Excell (2011) explained that failure to promote careers in engineering for women will mean that we will continue to miss out on 50 per cent of the available talent, an oversight which could have serious repercussions for society and the future strength of the economy

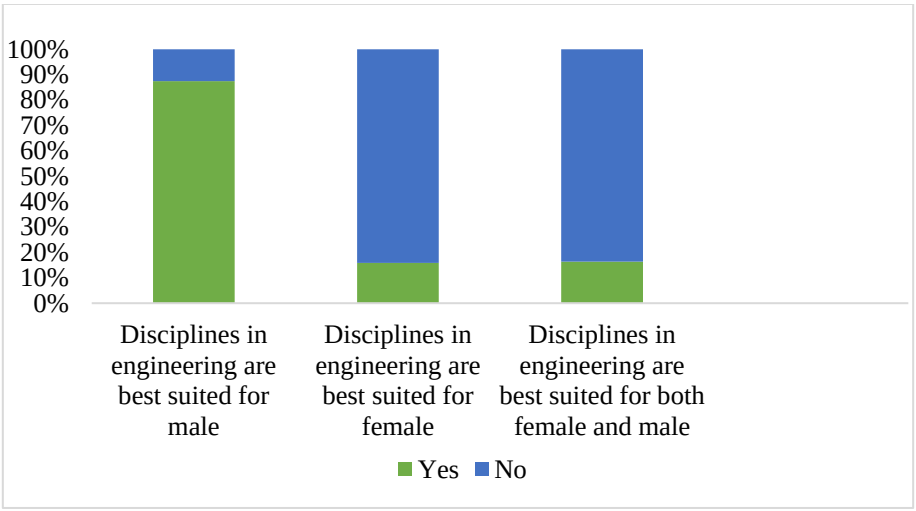

Figure 2. Female Students' Perceptions of the Gender of Engineers

Factors That Influence Female Students' Career Choice in the Fields of Engineering

Findings in Table 1 show the various factors that influence female students' choice of career in the disciplines in engineering. Some of the personal self-acclaimed factors that they perceived engineering as a difficult course, they are scared about the negative information passed around about engineering and lack of interest in constructing and operating of machines or equipment. The school factors that influence their choice are lack of adequate awareness and exposure about the fields in engineering; poor teaching facilities; school counselor' s untimely advice about the fields in engineering; and dearth of motivation by teachers. A study by Camacho and Cordova-Wentling (2006) posited that school factors such as lack of access to career-related information and exposure; dearth of tutelage from school counselor on engineering disciplines; inability to attend high schools with math/science/technology course opportunities were the frequent challenges encountered by high school students.

Table 1. Factors That Influence Female Students' Career Choice in the Fields of Engineering

S/N	Statements Describing Perceptions	Students' Responses	
		Yes%	**No%**
Personal Factors			
i.	Engineering field appears to be difficult and challenging for females	326 (89.1%)	40 (10.9%)
ii.	Negative information given about engineering careers scare me	256 (69.9%)	110 (30.1%)
iii.	I do not have interest in building and operating of machines or equipment	266 (72.7%)	100 (27.3%)
iv.	I lack the knowledge of the prerequisite subjects like Mathematics, Physics and technology.	28 (7.7%)	338 (92.3%)
v.	Engineering is not as lucrative and prestigious as other science fields	140 (38.3%)	226 (61.7%)
vi	Engineering requires lot of drawing, thinking and calculations which I dislike	50 (13.7%)	316 (86.3%)
School Factors			
i.	Limited career information and exposure about the fields in engineering	318 (86.9%)	48 (13.1%)
ii.	School teaching facilities do not encourage me to study engineering	210 (57.4%)	156 (42.6%)
iii.	Lack of advice from school counselor on engineering career options	320 (87.4%)	46 (12.6%)
iv.	Lack of encouragement from teachers	286 (78.1%)	80 (21.9%)
Family Factors			
i.	Lack of assistance in math/science/technology homework at home	312 (85.2%)	54 (14.8%)
ii.	Lack of family female role models and/or mentors who studied engineering	262 (71.6%)	104 (28.4%)
iii.	My parents want me to pursue degrees in fields like nursing and medicine	354 (96.7%)	12 (3.3%)
iv.	Lack of financial support from parents to finance engineering in tertiary education	180 (49.2%)	186 (50.8%)
v.	My parents are not knowledgeable about the fields of engineering because they are not educated.	74 (20.2%)	292 (79.8%)
Societal Factors			
i.	Engineering is generally accepted as a male dominated field	232 (63.4%)	134 (36.6%)

S/N	Statements Describing Perceptions	Students' Responses	
		Yes%	No%
ii.	Insufficient women engineers as role models/mentors in my area	234 (63.9%)	132 (36.1%)
iii.	Male's chance of recruitment is higher than female	322 (88.0%)	44 (12.0%)
iv.	I do not want to study engineering because my friends do not want to study it	204 (55.7%)	162 (44.3%)
v	Both male and female members of the community who studied engineering are not gainfully employed like people who studied medicine and nursing	298 (81.4%)	68 (18.6%)
vi.	Limited number of industries and non-creation of industries	360 (98.4%)	6 (1.6%)

Another factor is the family factor. Respondents reported that inability of their family members to help them with their assignment, absence of female family members to be their mentor/role models in the field of engineering, and parental will and preference to biological and health science courses are the major reasons. Camacho and Cordova-Wentling (2006) recorded that lack of parent financial support, parents' lack of knowledge about the engineering, lack of family role models/mentors, and parents' preference of a degree in a different field contributed to their choice of career. Valls et al. (2018) noted that regarding intrinsic motivations of career choice, women exhibit a higher preference and interest in the field of humanities, topics related to social issues and awareness. Regarding intrinsic motivations of career choice, women are affected by social influence, especially that of parents.

The societal factors that were raised in the present study are the general conception held in the society that engineering is meant for male; inability to know many female engineers in the community; greater chance for men to secure employment after graduation, peer's influence; low morale on the part of large numbers of unemployed male and female who have graduated compared to others who studies biological and health sciences; and insufficient number of industries and non-establishment of industries according to the fields of engineering where engineers can work. Camacho and Cordova-Wentling (2006) noted that the low representation of women in the engineering workforce (which contributes to the public image of the engineering field being mostly male and the lack of female engineering role models/mentors in society), and the traditional views about careers/education for women do hinder female students when they are deciding to pursue a degree in engineering.

In addition, access to role models and mentors influences successful professional development. Young adults identify with successful female role models whose presence allows them to think: "If she can be successful, so can I" and "I want to be like her." (Dasgupta & Stout, 2014). Alawi and Al Mubarak (2019) observed that the low number of females in STEM is caused by factors such as stereotypes that begin from early years of a child and extend to professional life. These stereotypes are caused by family, school, university, and other community institutions such as media and religious institutions. To end this trend, all these institutions play important parts

in correcting all the misconceptions, myths and impressions that scare female folks away from studying engineering.

Conclusion

It was concluded in the study that there exists gender discrimination in the choice of female students' career in the field of engineering. To abate this surge, there is the need to nip the thought of male chauvinism in the bud as early as possible at home, school, university, and other community institutions such as media and religious institutions. Novel ideas keep involving and female folks can not be left behind. The involvement of females in the field of engineering will definitely bring about sustainable knowledge acquisition in the fields of engineering, and as well contribute to knowledge production and all-round social-economic development needed in the 21st century. Changing female students' negative orientation about engineering will help to produce female engineers who are smart, logical, analytical, solution-driven, and creative.

Recommendations

Based on the findings and conclusion made in this study, the following were suggested as recommendations:

i. female children should be informed that there is no difference between boys and girls except for biological make up; they both have equal ability, capacity, rights, and duties in the society.
ii. females should be trained in spatial skills which are necessary for success in engineering and scientific fields just as males.
iii. notable females who are engineers in different fields should be invited as resource persons; they can serve as good models for girls in the fields of engineering. This can boost the morale and self-confidence of female students to when they see successful women who are professionals.
iv. school counselors should counsel females in schools on their career paths.
v. there should be adequate provision of various updated teaching and learning facilities that would endear females to study engineering.
vi. viable industries should be provided by the government and private individuals, and students too can be taught how to be self-employed.

Limitations

There were limited number of respondents who participated in the study. This makes the findings less representative and cannot be used for generalization. Further study could be a comparative study of both public and private female school students' knowledge and perceptions of engineering using a bigger sample.

Ethics and Conflict of Interest

The consent of the respondents was sought, and they were informed of the purpose of the study. Their

confidentiality and anonymity were assured because respondents' information was not disclosed. Participation was made voluntary. Authors declare that there is no conflict of interest.

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