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RESEARCH ARTICLE

Trends of Women's Participation in Engineering Education in the Republic of Benin and Implications for the Future of Higher Education

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ABSTRACT

Engineering, as well as men's and women's valuable labours or contributions, are important for the socioeconomic development of countries. This reality and the lack of data in this field in developing countries brought this paper's authors to investigate the extent to which female and male students are enrolled and graduate in engineering education faculties in the Republic of Benin, a West African country. To this end, statistics of enrolment, graduation, failure, and exclusion of female and male students of the two oldest engineering education faculties, i.e., the Polytechnics School of Abomey-Calavi (EPAC) and the Faculty of Agricultural Sciences (FSA) of the University of Abomey-Calavi (UAC), have been estimated using Excel software and available enrolment, and academic results' books and database. Pedagogical bylaws and other education policy documents were also reviewed for the sake of understanding the gender participation trends of the studied faculties. The analysis of almost four decades (1985–2022) of data revealed that very few (about 4,912, including 694 women) students got enrolled in the engineering programmes of the studied faculties. The total number of engineering students enrolled in the two faculties represents less than 1% of the total number of those who got their baccalaureate over the study period. Of the total number of women enrolled over the four decades, about 25% got excluded, while only about 22% of men got excluded at the polytechnic school EPAC. Meanwhile, at the Faculty of Agricultural Sciences FSA, 2% of the women enrolled were excluded against 1% of men. These results show that students are more excluded in the industrial engineering programmes of the polytechnic school compared to the agricultural engineering programmes of FSA. The main reasons identified for the small number of students enrolled in the engineering education faculties were, among others, the limited number of scholarships and places given to the engineering programmes by the government, donors and the faculties due to limitations in infrastructure and other resources available. With regards to the very poor participation of women in engineering programmes, socio-cultural stereotypes, poor social support or care provided to ladies and women, poor gender-responsiveness of STEM education and pedagogies, poor and late information on the advantages of engineering education and careers, sexual harassment, and early pregnancy, are few of the reasons mentioned by interviewees. More advocacy and more gender-responsiveness of further interventions might help improve the overall number of engineering students and the participation of women and other valid but less-represented people in engineering education programmes in universities of the Republic of Benin.

Keywords: Curricula and pedagogy, Gender-responsive infrastructure, Inclusive engineering education, Socioeconomic development.

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1. Introduction

Engineers remain essential for the sustainable development of any nation (Wall, 2010; Huyer, 2015; Magjarević, 2021). They contribute to innovation, industrialisation, technological and economic development, as well as to the well-being of human beings. Several international organisations increasingly acknowledge the significant role of engineers in nations' development processes. For example, according to the Centre for Economics and Business Research (CEBR, 2016), countries with adequate engineers experience a growing gross domestic product (GDP). In his address to participants of 2018 Web Summit on technological advances, the Secretary General of the United Nations, Mr António Guterres, also emphasised that each of the 17 sustainable development goals (SDG) requires solutions rooted in various fields, including engineering (Guterres, 2018).

The demand for engineering expertise is evident in various domains such as agronomy, civil engineering, mechanical engineering, computer science, and electrical engineering, among others. Therefore, engineering education is essential for achieving sustainable development goals and advancing humanity. However, many countries, especially those in the Global South, are facing an engineer shortage, and there is a low enrolment of students in engineering programs, particularly in these countries. A study published by Ecofin (2022) on capacity building in Africa revealed that Africa has 55,000 engineers while the market demands approximately 4.3 million, resulting in a deficit of around 99% (Ecofin, 2022). Furthermore, according to reports from the same organisation, global data on women's participation in engineering is unavailable; however, data from various developed countries such as Australia, Canada, etc., highlight the low level of women's participation in engineering (Huyer, 2015; Magjarević, 2021). Generating such data at the national level is one of the objectives of this study, which aims to assess the trend of students' enrolment in engineering programs over the past four decades in the Republic of Benin, with a particular focus on statistics related to women.

To achieve this study objective, the Faculty of Agricultural Sciences (FSA) and the Polytechnic School of Abomey-Calavi (*École Polytechnique d'Abomey-Calavi; EPAC*) were investigated. These institutions are the oldest engineering faculties or schools in the Republic of Benin and the most significant in terms of students' enrolment and graduation. The findings of this paper may help fill in the gaps of lack of factual and actual data on science, technology, engineering and mathematics (STEM) in general and on engineering education in the Republic of Benin. The following sections address the research methodology, findings, discussion, and conclusion.

2. Research Methodology

This section discusses data collection, treatment, and analysis tools and methods. The data collected relate to female and male engineering students' enrolments in the studied faculties between 1985 and 2022, as well as graduation, non-graduation or failure, and exclusion or drop-out rates over the study period.

2.1. Data Collection Tools and Methods

The target data were collected from the enrollment books of the faculties studied and through semi-structured interviews with resource persons. Due to a lack of records, not all academic years' data could be found and analysed. The resource persons interviewed were registration and archives officers of both faculties, and their roles were to help access, understand, and validate the registration data and trends. Furthermore, we referred to the history and other details of the faculties, the University, and the education system to explain the recorded trends.

2.2. Data Treatment

The data collected were first transcribed, transferred, and entered into a spreadsheet. Next, the data were arranged per academic year, programme or field of study, level, and gender to ease their analysis.

2.3. Data Analysis

The data analysis consisted mainly of calculating registration frequencies and percentages per academic year, gender, and engineering programme with Microsoft Excel. These processed data helped construct registration, graduation, failure, and exclusion trend graphs. The graphs are later on logically interpreted concerning the literature and the sustainable development goals or UNESCO engineering education targets, and some conclusions and implications are inferred. Table I summarises the methodology used.

TABLE I: Overview of the Research Methodology

Data and sources per studied faculty	Data collection tools and methods	Data treatment and analysis tools and methods
• Number of enrolments per gender and per academic year (AY); • Number of graduations per gender over the study period • Number of failures per gender over the study period • Number of exclusions per gender over the study period • Sources: Enrolment and AY results' books and semi-structured interviews • AY covered: 1985–2021 for EPAC; and 1990–2022 for FSA due to the availability of data	• Semi-structured interviews with registration and archives officers (use of interview guide) • Photocopy and scanning of non-digital data sources • Copy of digital data files	• Transcription of non-digital data in Excel sheet • Transfer of digital data to an excel sheet • Calculation and comparative analysis of frequencies and percentages per gender, academic year, and students' results • Construction and comparative analyses and interpretations of graphs concerning literature and targets

3. Research Findings

In addition to the enrolment, graduation, failure, and exclusion trends, this section also addresses some background information on the studied faculties that may have affected the participation of women in engineering study programmes.

3.1. Background Information on the Studied Faculties

Table II summarises the history and some of the background information of the Polytechnics School of Abomey-Calavi (EPAC) and the Faculty of Agricultural Sciences (FSA), which are the oldest engineering education schools, colleges, or faculties of the Republic of Benin (Presidency of the Republic of Benin, 2005; UAC, 2017).

3.2. First-Year Engineering Programme Enrolment Trends of the Studied Faculties

3.2.1. Case of the Engineering Programmes of the Polytechnics School of Abomey-Calavi (EPAC)

Fig. 1 shows how the numbers of first-year engineering students enrolled at EPAC evolved between 1985 and 2021 and per gender.

TABLE II: Background Information on the Studied Engineering Faculties EPAC and FSA

Description	EPAC	FSA
Date of creation	1977	1970
Admission criteria	• Scientific Baccalaureate (C [major in mathematics and physics]; or D [major in mathematics and life and earth sciences]); • Technical and industrial Baccalaureate (E or F) • No matter gender, origin, tribe/ethnic group/race • Number of places available • Admission to contest or other selection criteria • Availability of scholarships or funding	• Scientific Baccalaureate (C; D); • Technical Baccalaureate (DEAT [major in tropical agronomy]) • No matter gender, origin, tribe/ethnic group/race • Number of places availability • Admission to contest or other selection criteria • Availability of scholarships or funding
Branches	Biological and industrial	Technical and engineering
Engineering programmes offered	• Environmental engineering • Civil engineering • Electrical engineering • Mechanical and energetic engineering • Computing and telecommunication engineering • Chemical engineering • Biomedical engineering • Agricultural machinery engineering	Agricultural engineering with a major in: • Crop production, • Animal breeding, • Food technology and nutrition • Mechanization, • Economics, social anthropology and communication for rural development, • Natural resource management
Degrees delivered	Bachelor, Master, Engineering, Doctorate (biological and industrial fields)	Bachelor; Master; Engineering; Doctorate (technical and agricultural engineering programmes)

TABLE II (continued)

Graduation, failure, reorientation, and exclusion rules for engineering programmes	Up to 2010 (before the adoption of the BMD or LMD system in Benin) • Graduation: when average grade ≥ 12/20, and no failure or exclusion in fundamental and speciality subject matters; • Failure: when the average grade comprised between 10/20 and 12/20 • Exclusion: at second failure in the same class or the same cycle; or when average grade <10/20; or when the student gets grades less than 8/20 in two fundamental or speciality subject matters or one fundamental and one speciality subject matter in first-year; or when the student gets less than 10/20 in fundamental and speciality subject matters from second-year onward Since 2010 (adoption of BMD or LMD) • Graduation: if grade ≥12/20 per Learning Unit* and if 80% of the total number of learning units are validated. No failure (grade <12/20 per learning unit) is admitted for engineering students in the first and second years • Failure: When the total number of learning units validated/graduated (grade ≥12/20) by a student is comprised between 20% and less than 80% • Reorientation: When the total number of learning units validated/graduated (grade ≥12/20) by a student is less than 20% Exclusion: When the student drops out for personal reasons or fails two times in the same class or cycle	• Graduation: when average grade ≥12 • Failure: when mark <8/20 and/or average grade <12/20 in any subject matter; • Exclusion: at second failure in the same class or the same cycle; or when average grade <8/20

Note: BMD: Bachelor–Master–Doctorate in French; LMD: Licence–Master–Doctorate in French. There are three cycles at universities: The bachelor cycle (first three years or first six semesters), the master cycle (fourth and fifth years or seventh to tenth semester), and the doctorate cycle (sixth to eighth years or eleventh to sixteenth semesters, where the rules are different).
*A learning unit is called Unité d'Enseignement in French, and it comprises one to 3 courses or subject matters.

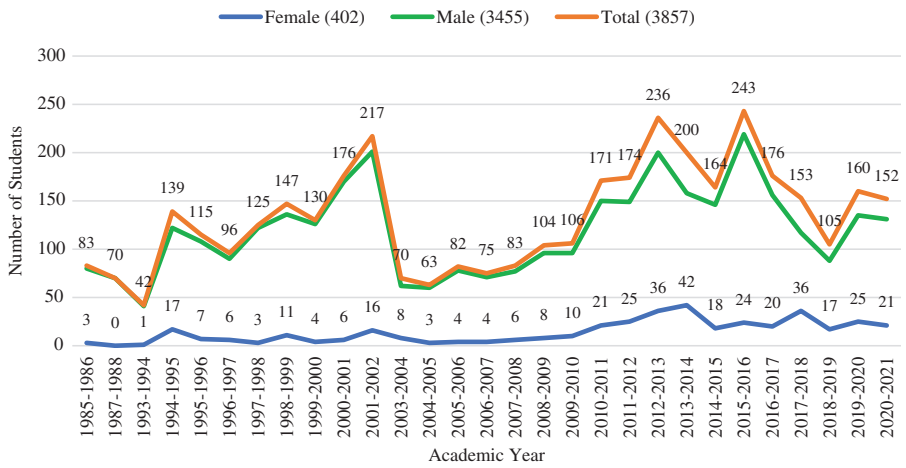

Fig. 1. Trends of enrolment of first-year engineering students at EPAC per gender between 1985 and 2021 (Source: EPAC, 2004, 2021).

Fig. 1 indicates that data from sixteen academic years (1977–1985, 1986-1987, 1988–1993, 2002–2003, 2021–2022) are missing. It also shows that of the 3,857 engineering students enrolled in the first year between 1985 and 2021, nine out of ten (9/10) were men, while women represented only 10.42% (1/10). Considering all the above 29 cohorts of first-year engineering students, the average total annual number of students enrolled is 133. This average annual enrolment number is about 14 for women and 119 for men.

Furthermore, the highest number of women (42) was registered in 2013, while the smallest one (0) was registered in 1987. Meanwhile, the highest number of male students (219) was recorded in 2015,

while the lowest (41) was recorded in 1993. The analysis of the enrolment percentage trends shows that the relative proportion of enrolled women ranged from 0% (in 1987–1988) to 24% (in 2017–2018), while the relative proportion of male students oscillated between 76% (in 2017–2018) and 100% (in 1987–1988).

3.2.2. Case of the Engineering Programmes of the Faculty of Agricultural Sciences (FSA)

Fig. 2 shows the first-year enrolment trends of the engineering students of FSA from 1990 to 2022.

Fig. 2 reveals that data from 28 academic years (1970–1990, 2000–2001, 2007–2014) are missing. It also indicates that a total number of 1,130 students (including 292% or 26% of women and 838% or 74% of men) got enrolled over the 24 academic years covered by the study. This means that three out of ten (3/10) enrolled students were women. Further analysis indicates that an average of 45 students (11 women versus 34 men) were yearly enrolled over the study period. The highest number of female students (25) was registered in 2006–2007, while the lowest one (0) was enrolled in 1990–1991 and 1991–1992. Meanwhile, the highest number of male students (60) was registered in 2006–2007, while the lowest one (15) was enrolled in 1991–1992. The highest relative proportion of enrolled women is 47% (in 2021–2022), and the lowest one is 0% (in 1990–1991 and 1991–1992).

3.3. Graduation, Failure, and Exclusion Rates of First-Year Students of the Studied Faculties

3.3.1. Case of the Engineering Programmes of the Polytechnics School of Abomey-Calavi (EPAC/UAC)

Fig. 3 shows the average rates of graduation, failure (non-graduation), and exclusion of the first-year engineering students enrolled over the study period (1985–2021).

In general, Fig. 3 shows a total graduation rate of 71.79%, a total non-graduation or failure rate of 5.76%, and a total exclusion rate of 22.62% (out of 3,857 students enrolled). Gender-specific analysis reveals that graduation, failure, and exclusion rates were respectively 71.9%, 5.76% and 22.32% for male students. Meanwhile, graduation, failure and exclusion rates were respectively of 70.9%, 3.73% and 25.37% for female students over the same study period. These data suggest that not only fewer (about

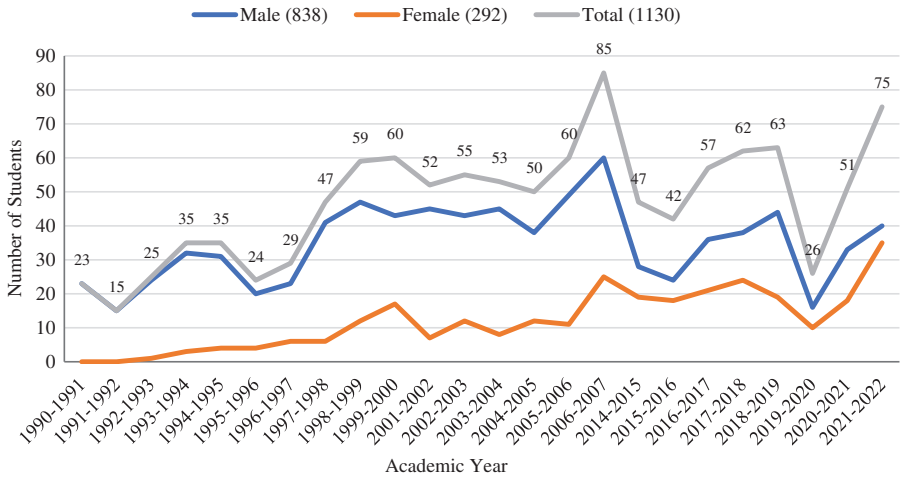

Fig. 2. Trends of enrolment of first-year engineering students at FSA per gender between 1990 and 2022 (Source: EPAC, 2022).

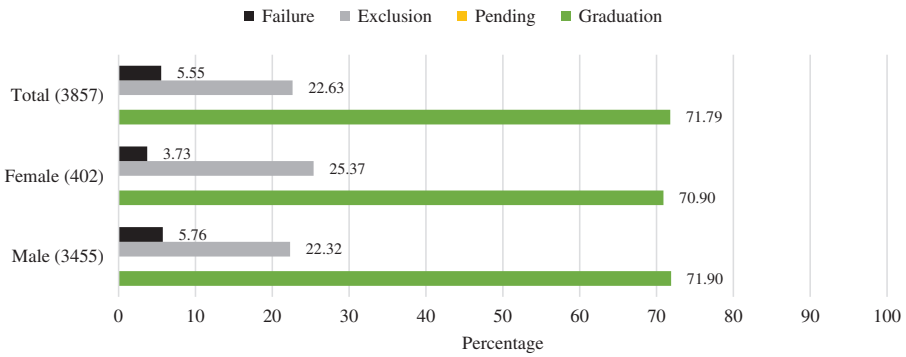

Fig. 3. Total graduation, failure, and exclusion rates of first-year engineering students enrolled at EPAC between 1985 and 2021. The numbers in parentheses refer to sample sizes.

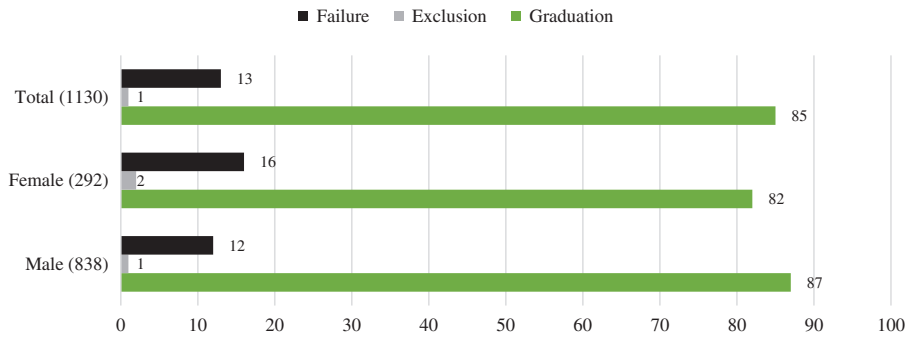

Fig. 4. Graduation, failure, and exclusion rates per gender of first-year engineering students at FSA/UAC between 1990 and 2022.

10.42%) women got enrolled in engineering programmes, but proportionately less of them graduated and more of them got excluded than men.

3.3.2. Case of the Engineering Programme of the Faculty of Agricultural Sciences (FSA)

Fig. 4 gives a gender-specific overview of the total graduation, non-graduation, and exclusion rates of engineering students enrolled at FSA between 1990 and 2022.

Fig. 4 indicates total graduation, failure, and exclusion rates of 85%, 13%, and 1%, respectively. Gender specifically, it respectively reveals total graduation, non-graduation, and exclusion rates of 87%, 12%, and 1% for male students and 82%, 16%, and 2% for female students. Such results demonstrate that not only fewer (26%) women enrolled in engineering programmes, but they proportionately failed and were excluded more than men.

4. Discussion

This paper addresses the trends of enrolment, graduation, failure and exclusion rates of male and female students in the two oldest engineering education faculties (the Polytechnic School of Abomey-Calavi; EPAC and the Faculty of Agricultural Sciences; FSA), from the University of Abomey-Calavi (UAC), the oldest public and multi-thematic university of the Republic of Benin. The study covered the period of 1985 to 2022, based on availability of data. Considering the date of creation of the faculties and the study periods, sixteen academic years' data are missing for EPAC (1977–2022), and those of twenty-eight years are missing for FSA (1970–2022) due, among other reasons, to poor storage, access, and retrieval possibilities; and, absence of academic activities and quality data records. For example, the research team unsuccessfully managed to access some enrolment and graduation books of the two faculties because the registration and archives officers did not know where to find most of the data from the 1970s and the 1980s, and there were no records in 1988–1989 because of strikes and whitening of the year. This finding raises concern about the quality monitoring and evaluation data recording, storage, retrieval, sharing, and use capabilities of the studied faculties, which may compromise the quality evidence-based decision and intervention possibilities of those faculties' decision-makers. Meanwhile, quality evidence-based decision-making and interventions are required for effective development.

The study also revealed that a minimum of 42 (including one female in 1993) and a maximum of 243 (including 24 females in 2015) students were registered at EPAC, against a minimum of 15 (including 0 female in 1991) and a maximum of 85 (including 25 females in 2006) at FSA. Moreover, the results inform that an average of 133 ± 53 (including 10.42% female) and 47 ± 17 (including 26% female) students were respectively enrolled in the first year of engineering programmes of EPAC and FSA each year between 1985 and 2022. From these data, one may easily infer that EPAC enrols on average more engineering students (three times) than FSA, but both faculties register together less than 200 engineering students on average per year, which represents about 0.88% (4,912) of the total number (559,081) of those who got their baccalaureate during the study period (1985–2021). Considering the total population (12,640,000) of the Republic of Benin in 2020, one would state that both engineering education faculties have released about four engineers (all 14 studied programmes included) for 10,000 people on average between 1985 and 2021. This ratio may be among the best in the world, but it may still be far from the trends in the most developed countries, which turns around one engineer for 100 inhabitants (Nair-Bedouelle, 2021; Schneegans *et al.*, 2021; Wall, 2010; UNESCO, 2017; Magjarević, 2021).

Regarding gender specificity, one can observe that, on average, female engineering students represented 14% (out of 4,912) for both faculties, which is far from 50%, but not the least of the world, considering UNESCO's statistics (Wall, 2010; Huyer, 2015; Magjarević, 2021). More specifically, one

can also notice that the participation of women in the engineering programmes has progressed sinusoidally over time in both faculties, but with faster progress for agricultural engineering programmes of FSA (0%–47% females, with an average of 26% over the study period), compared to industrial engineering programmes of EPAC (0%–24% females, with an average of 10.42% over the study period). This means that the gender gap is closing rapidly in the agricultural engineering programmes and slowly in the industrial engineering programmes, probably due to the low participation of women in the Science-Technology-Engineering and Mathematics (STEM) programmes (e.g., E and F programmes) of high secondary schools, required to access some of the industrial engineering programmes at university. Besides, according to interviews and historical information, the closing of the gender gaps in the studied engineering programmes would be due, among other reasons, to awareness campaigns, advocacies, lobbying, mentorships, role models, scholarships, and some positive discrimination changes in gender policies in favour of women.

Looking at the exclusion rates, female students were relatively more excluded in both faculties (25% for females versus 22% for males at EPAC and 2% for females versus 1% for males at FSA) during the study periods. These exclusion-related results confirm the extent to which the very few (10.42%) women enrolled in industrial engineering programmes of EPAC may face some specific STEM-related subject matters' graduation challenges compared to their fellows (26%) in the agricultural engineering programmes of FSA. This finding confirms, to some extent, the still high inclination for and the presence of women in life and care-related disciplines and employment (Nair-Bedouelle, 2021; Schneegans *et al*., 2021). It also raises concern for further measures to mentor, protect, and avoid exclusion or drop-out for the currently very few women engaged in STEM and engineering education and careers. Further investigation may help understand the specific challenges faced by female students in the engineering programmes of the studied university faculties.

5. Conclusion and Implications

5.1. Conclusion

This paper discusses the trends of enrolment and the rates of graduation, failure and exclusion or drop-out of female and male students in engineering programmes of the two oldest engineering education faculties of the University of Abomey-Calavi and of the Republic of Benin, in West Africa. The studied engineering programmes are industrial programmes of the Polytechnic School of Abomey-Calavi (EPAC) and the agricultural engineering programme of the Faculty of Agricultural Sciences (FSA). The data used were collected from the enrollment and graduation books of the faculties studied from 1985 to 2022. These data were transcribed or transferred and treated in Microsoft Excel sheets and used to construct tables and graphs for the visualisation, analysis and interpretation of the intended trends and rates. In all, the data analyses revealed that less than 1% of the 559,081 people who got their baccalaureate during the study period (of 1985–2021) enrolled in the engineering programmes of the studied faculties.

The data also indicated that, on average, more men were enrolled in the engineering programmes (89.58% at EPAC and 74% at FSA) than women (10.42% at EPAC and 26% at FSA) during the study period. Considering the enrolment trends, it was noticed that the participation of women in the engineering programmes has evolved, moving between 0% and 24% at EPAC and between 0% and 47% at FSA, suggesting that gender gaps have been closing slowly at EPAC (where there are industrial engineering programmes), and faster at FSA (where there are agricultural engineering programmes). Regarding graduation and exclusion rates, there were more exclusions of women (25% at EPAC and 2% at FSA) than of men (22% at EPAC and 1% at FSA) in both faculties, but the rates are higher in the industrial engineering programmes of EPAC than those of the agricultural engineering programmes of FSA. Thus, from an exclusion point of view, the gender gap is still real in the studied engineering programmes, although it is closing. Further study may help elucidate the reasons behind these gaps in-depth. Once the reasons for the gaps are further known, accurate measures will be suggested to the engineering education system's stakeholders toward equitable participation of both men and women in these programmes.

5.2. Implications

The findings above raised an issue of lack of data in the studied faculties. Given the importance of quality monitoring and evaluation data for quality diagnosis, decision-making, and planning, relevant measures are required to be taken against issues of lack of enrolment, graduation, failure, exclusion, and other useful data in university faculties. This means that faculties and universities need to–define relevant management indicators and hire, equip, and adequately motivate competent archivists, data management, and monitoring, evaluation and learning specialists–to prevent the absence of important management data and to improve their management quality.

Taking more than 30 years to release 1 engineer for about 2,500 inhabitants implies that the studied faculties will require at least 25 times 30 years before reaching the ratio of 1 engineer for 100 inhabitants, as this is the case in some developed and emerging countries like Denmark and South Korea (Magjarević, 2021). Engineers and engineering are very important for the socioeconomic development of countries (Ecofin, 2022; Wall, 2010). Thus, more effort may be deployed to increase the quality and the number of engineering graduates in the studied faculties and universities. Required efforts may relate to the increase of investment in inclusive infrastructure, gender-responsive engineering education curricula and pedagogy, and inclusive student enrolment facilities, including scholarships for poor but qualified students.

Due to the importance of inclusion in education for the equitable development of societies (Wall, 2010; Magjarević, 2021) and to the proven relevance of awareness campaigns, advocacies, lobbying, mentorships, role models, scholarships, and gender policies in the gender gap closing in students' enrolment and graduation in faculties, these gender-sensitive measures may be adopted and promoted for more gender equity in faculties and universities. Such measures can be much more needed in industrial engineering programmes where gender gaps are higher than in life and care–and care-related engineering programmes such as those of agricultural engineering, as highlighted in this paper.

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Conflict of Interest

The authors declare that they do not have any conflict of interest.

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