



Women in engineering, science and technology in sub-Saharan Africa: cultural attitudes, challenges, and gaps affecting clinical engineering and medical devices maintenance practices

Alessia Maccaro¹ · Iyabosola Busola Oronti^{1,2} · Eugenio Zito³ · Davide Piaggio¹ · Leandro Pecchia^{1,4}

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Abstract

Purpose From previous studies, we had observed that the number of biomedical engineers and technicians (BMETs) skilled in the maintenance of medical devices (MDs) were limited in sub-Saharan Africa (SSA) and that a likely *parallelism* existed between BME maintenance-related tasks and house chores mainly carried out by women in daily life. Our objective in carrying out this study was to understand underlying local cultural and social factors and domestic traditions interfering with the inclusion of women in the field of clinical and biomedical engineering (BME), and to identify existing gaps in opportunities for women in Engineering, Science and Technology (EST) in this region.

Methods We carried out an online survey involving 51 respondents (70.6% women, 29.4% men), to investigate gender-biased and cultural perceptions of maintenance-related tasks among engineers/technologists/technicians in BME and other allied professions in SSA. The survey was refined through focus groups and pilot tests to assess its validity, and then shared among specific associations of women in engineering and other bodies in EST, as well as some hospital communities and institutions.

Results The survey brought to light evidence of prejudices against women in the society and workplace and showed that the adoption of our *parallelism hypothesis* has potential for increasing medical device maintenance practices in SSA hospitals.

Conclusions There is an apparent need to further study the possible effects of this sociological model through leveraging local culture and domestic traditions in ways that could ultimately increase the leadership and numbers of women BMETs in SSA.

Keywords Women · Sub-saharan Africa · Engineering, science, and technology · Medical devices · Maintenance · Biomedical engineers and technicians

1 Introduction

Biomedical engineers provide meticulous care for MDs, procure high-end equipment, manage maintenance contracts, and oversee the overall structure of the hospital, including floor plan design. Observations from field studies carried out in SSA [1–4] showed that, overall, there is a limited number of practising biomedical engineers in this region, and that most often than not, BME professionals were more likely to be substituted with technicians in hospitals; either internally (i.e., within the hospital), or when called out for emergencies (e.g., in the case where devices and equipment malfunction and it is not possible to directly access the manufacturer). These studies also documented the fact that many BMETs working in hospitals in low

✉ Iyabosola Busola Oronti
Iyabosola.Oronti@warwick.ac.uk; busola.oronti@gmail.com

¹ School of Engineering, University of Warwick, Coventry, UK
² The Applied Biomedical Signal Processing and Intelligent eHealth (ABSPIE) Laboratory, School of Engineering, University of Warwick, Coventry, UK
³ Department of Social Sciences, University of Naples Federico II, Naples, Italy
⁴ University Campus Bio-Medico, Rome, Italy

resource settings (LRSs) are not particularly skilled in the maintenance of MDs. In a general sense and particularly in healthcare settings, maintenance of medical equipment and devices is defined by activities and strategies deployed to ensure their reliability, longevity, optimal performance, and safety. Moreover, effective maintenance practices are key to reducing downtime, ensuring continuous equipment availability and reducing costs [5, 6]. Maintenance strategies are usually classified into corrective, preventive, and predictive maintenance.

In SSA, we found that most job specifications are usually limited to the corrective rather than the preventive aspects of maintenance, while in more advanced settings, preventive maintenance is the most commonly implemented in hospitals. Corrective maintenance is performed only when an equipment or device breaks down. Preventive maintenance is performed on a regular basis within a scheduled time or after a certain amount of equipment usage irrespective of the condition. Predictive maintenance is an advanced maintenance strategy which leverages technology, data, and analytics to predict equipment failure or performance degradation [5, 6]. New innovations in predictive maintenance strategies employ historical data (e.g., time series and big data), real-time device monitoring (sensors and sensor networks), data analytics and AI (machine or deep learning algorithms and statistical models), smart technologies (e.g., internet of things (IoT) and cloud computing,), etc. to predict maintenance timelines for MDs. In addition, advanced technologies such as augmented reality (AR), virtual reality (VR) and mixed reality (MR), as well as blockchain and robotics are also being used in different ways to increase the accuracy and efficiency of MD maintenance practices, and can also be harnessed for training purposes [7–9].

For example, utilizing an internet of things (IoT) based maintenance strategy that incorporates sensors for collecting normal and failure related real-time data will provide a better picture of equipment health by providing status warnings that can induce scheduling a maintenance action before the MD breaks down. Further, data analysis tools and machine learning/deep learning algorithms can be incorporated to predict and classify healthy and faulty equipment status. Adapting this method can shorten diagnostics time to uncover failure causes, minimize spare parts inventory holding costs, lower maintenance costs and effort, allow better capacity planning, and assess the usage and functionality of MDs [10, 11]. Soft savings such as patient satisfaction and shorter times to patient diagnosis can also not be overlooked [8]. Extended reality (XR) – comprising of augmented reality (AR), virtual reality (VR), and mixed reality (MR) – is an umbrella term for any sort of technology that changes known reality by adding digital elements to the physical or real-world environment by any degree, thus blurring the line

between the physical and digital world. These technologies differ in how much they rely on physical or digital elements. Specifically, AR technology allows the superposition of digital elements into the real-world environment; VR allows the creation of a fully immersive digital environment; MR allows the user to see and interact with both digital and physical elements. These technologies can be used to support maintenance of MDs for clinical practice. Examples of use in the literature include guidance through unfamiliar maintenance tasks and visualization of information directly in the spatial context of AR, location of spare parts and sending maintenance repair instructions over mobile devices [10, 12], and mobile app offering detailed information about different MDs using AR [13]. Likewise, VR can be used in maintenance training/education, aid in the resolution of complex maintenance challenges by inexperienced BMETs, and facilitate the simplification of user/maintenance guides [14]. Finally, as previously mentioned, AI can significantly enhance and supplement the work of BMETs by providing real-time monitoring, predictive maintenance, and troubleshooting support [6, 14, 15].

Interestingly, an aspect of maintenance-related tasks that is usually overlooked is the issue of sociocultural perspectives, which suggests that maintenance tasks are perceived as unattractive and degrading by men. From an analysis of the culture prevalent in the SSA countries that were visited in these studies, we noticed that despite being patriarchal countries [16–18], women traditionally play leading roles in tasks pertaining to the maintenance of the house and family [17, 19]. The observations and results documented in these studies led to the research hypothesis driving this present study, which is a collaborative effort between researchers with different competencies such as biomedical engineers, clinical engineers (CEs), electrical and electronics engineers, mathematicians, economists, sociologists, and bioethicists - all with a peculiar interest in LRSs. Because of the multidisciplinary nature of this work, our initial research questions were approached from different perspectives, such as the humanistic and technical angles, with particular attention to the subjective (i.e., sociological, ethical, religious and local culture contexts) and objective aspects (i.e., clinical engineering measurements within hospitals, including the analysis of the quality of the electrical current, the availability and working status of medical devices, the possibility of procuring spare parts, and the accessibility of specialised users).

According to Shoola [20], the cultural-ideological concept of hegemony [17, 21] is pervasive in SSA societies and is held by the ruling elite. Even though a few exceptions exist such as the case of the Akan of Ghana, the true picture is that numerous facets of life in SSA (e.g., the political, economic, educational, and legal aspects) are dominated

and controlled by men. This cultural concept whereby males are given or assume positions of power that are not usually available to women, therefore, supports the observation that the number of women working as BMETs is very low. It is noteworthy, however, that although these notions are mainly exacerbated in regions such as these, gender bias is still an existing challenge, even in higher-income countries like those in Europe [22], with many domains being affected such as pay inequalities or diversity in leadership roles. The scant involvement of women in science is also a lingering challenge in these countries. However, years of campaigns and tailored initiatives contributed to mitigating the negative effects of this phenomenon.

To have a better idea of the critical nature of the phenomenon in SSA, some of the authors of this study did a comparison between enrolled students in the BME faculties in the University of Abomey-Calavi (Benin) and the Polytechnic University of Turin (Italy). As of November 2019, between six to eight women were enrolled in the biomedical engineering faculty of the University of Abomey-Calavi, compared to 45–50 men, which equates to about 13.8% females and 86.2% males. Comparatively, the Polytechnic University of Turin had 54.6% females and 45.4% males enrolled for the same course of study in 2019. It should be noted here that these numbers are quite high for the Polytechnic University of Turin in respect of other engineering streams, e.g., mechanical engineering – a course where only 14.6% of the students were females in 2019. However, if we apply this same reasoning, we can expect the numbers to be even lower, if not null, for mechanical engineering students in the University of Abomey-Calavi. It is also interesting to note that out of all students enrolled at the University of Abomey-Calavi in any particular year, only 20% (10% of which are females) will continue their education to PhD level¹. The limited number of BMETs, coupled with the gender-biased cultural perception of maintenance culminates in the inability of the BMETs' leadership to negotiate increased budget allocations for BMET personnel and clearly articulate the importance of BMETs' role in maintenance tasks in SSA and more generally, in hospitals situated in LRSs. This situation leads to incredibly low availability of funds, tools, and training for maintenance tasks, which are vital for the safe and effective functioning of medical devices.

Moving on from these observations, we decided to deepen our understanding of the experiences of women in EST in LRSs, by leveraging local cultural factors and domestic traditions to investigate gender-biased and cultural perceptions of maintenance-related tasks among engineers/technologists/technicians in BME and other allied professions, who maintain and repair medical devices in LRSs.

¹ <https://www.polito.it/sites/default/files/2022-10/BdG%20Lite%20IT.pdf>.

We believe the results obtained from this study will help us better understand this phenomenon and could lead to the creation of sensitization and awareness programs that could increase the leadership and numbers of BMETs in SSA, with a special focus on women in the profession. Another important aim of this study is to create critical awareness of the importance of women accessing leading roles in maintenance of MDs through scientific and technical studies such as engineering within specific programs and in partnership with relevant associations. We believe this will increase the visibility of women in this much needed field and also significantly improve their employment into BME related professions in order to eliminate or reduce gender-biased inequalities.

2 Methods

The adopted methodology reflects a comprehensive theoretical approach which includes literature review, governmental and document analysis, and accessing different forms of communication routes such as the media, television, and online resources. In addition to this, we incorporated empirical research, which was based on a combination of surveys, ecological analysis, participation in public events (to allow topical discussions), and exchanges with experts in the field. As an additional output, the results of this study will be used to validate a previously created hermeneutic heuristic framework (HHF) [23].

From February to May 2022, an online survey was created with Google Modules and further refined through focus groups and pilot tests for assessing its validity [3]. The survey was then shared among specific associations of women in engineering and other bodies in EST, as well as some hospital communities and institutions in LRSs. Specifically, the survey was well received by the following associations and groups in Nigeria, namely: The Association of Professional Women Engineers of Nigeria (APWEN), The Nigerian Society of Engineers (NSE), The Biomedical Engineering Platform (BME/CE Nigeria), Teaching Hospitals, and Federal Medical Centers. In Benin, the survey was distributed to researchers at the University of Abomey-Calavi. We also circulated the survey among members of the International Federation of Medical and Biological Engineering (IFMBE) and the European Alliance of Medical and Biological Engineering and Science (EAMBES). The study was not gender specific and it included women and men interested in EST, while excluding experts in the humanities or researchers who did not originate from a LRS. The sample size was determined by the respondent saturation threshold, i.e., when we did not receive any new submission from survey respondents [24, 25]. All collected data were pseudonymized (only

individual emails, gender and age were collected) according to the general data protection regulation (GDPR).

The online survey (see Supplementary Material 1) was composed of 41 questions which were divided into five main sections, i.e., general questions, EST related, maintenance, COVID-19 pandemic, and other comments. The first section was aimed at collecting basic information such as the email address, gender, level of qualification, continent of provenience, country of work, and field of study of respondents. In the second section, we sought to deepen our understanding of EST-related issues by asking questions that would give us more information on the particular branch of engineering or engineering-related field each respondent had specialized in against the backdrop of any current involvement in the practise of clinical or biomedical engineering, the differences between technicians and engineers, the reason(s) behind choosing a career in the EST field, and any perceived prejudices and biases experienced by women in this field. Following on from there, all the questions in the third section were aimed at discovering maintenance practices in each respondent's workplace (i.e., hospitals), and how this relates to maintenance practices at home. This led us to ask questions about medical settings, the prevalence of women BMETs in the workplace and in BME leadership roles, the importance of maintenance tasks, perceptions on maintenance, etc. To support our interest in knowing whether there was any correlation between maintenance in the workplace and at home, we included a set of questions to compare maintenance of MDs and maintenance of the domestic environment according to local culture to learn more about the importance and role of engineers in relation to their gender. The fourth section focused on issues surrounding changes in the practice of biomedical engineering since the beginning of the COVID-19 pandemic. We wanted to know if there had been specific changes in the roles played by women in EST during the apex of the COVID-19 pandemic and whether maintenance tasks had assumed greater importance during this period. The fifth section was dedicated to feedback and further suggestions from the respondents. The number of respondents who took the online survey was 51 (70.6% women, 29.4% men) - all having a high level of qualification (BA, MA, PhD). 96.1% of respondents were from Africa (Nigeria, Ghana, Uganda), where the majority were also employed. The major field of pertinence was mostly Engineering (84.3%). The remaining 13.7% and 17.6% were from science and technology related fields. The full results are reported in Supplementary Materials 2 and 3.

3 Results

In this section, we report the results of the online survey that was aimed at identifying existing gaps in opportunities for women in EST, with a particular focus on SSA. We were interested in understanding if there were underlying cultural factors and social models which interfere with the inclusion of women in the field of clinical and biomedical engineering. Furthermore, gender-biased and cultural perceptions of maintenance-related tasks among engineers/technologists/technicians in BME and other allied professions, who maintain and repair medical devices in LRSs was investigated. Altogether, the work focuses on increasing women's awareness of their crucial role in EST, especially in LRSs.

3.1 EST related questions

Concerning the interests of respondents in engineering, most were qualified engineers/technicians/technologists (56.9%) or working as engineers/technicians/technologists (29.4%) or studying to be an engineer (9.8%) in the field of biomedical, electrical, chemical, civil, computer, industrial and mechanical engineering. Unfortunately, only 29.4% of respondents were actually employed as clinical or biomedical engineers (see Fig. 1). However, our results revealed a deep personal interest and passion for the field of BME by most respondents. To the question, "*What led you to choose this field of study?*"; apart from a frequent recurrence of words such as "*passion*", "*interest*", and "*love for the subject*", some interesting replies also included phrases like:

"I admire female engineers" (Ghana, 21/03/2022).

"I was inquisitive to venture into a less female dominated field of Engineering" (Nigeria, 25/02/2022).

Rarely did respondents express any form of limiting factors or restrictions to their choice of study. In cases where these were expressed, three major challenges were reported. These included societal issues, prevailing circumstances, and parental influence (e.g., 2% choose "*my family was against it*"). Moreover, it was interesting to note that the choice of field of study did not appear to be encumbered by any major obstacles, especially on the part of women and their choice to pursue this field of study. For example, 44.9% chose the option: "*it has always been my passion and I didn't care about the difficulties*" (see Fig. 2). From our results, we observed a good indication that it was not so unusual for women to be enrolled in EST courses in their respective home countries, and this was affirmed by a little less than half (41.2%) of the respondents.

Fig. 1 Percentages of respondents' interest in engineering

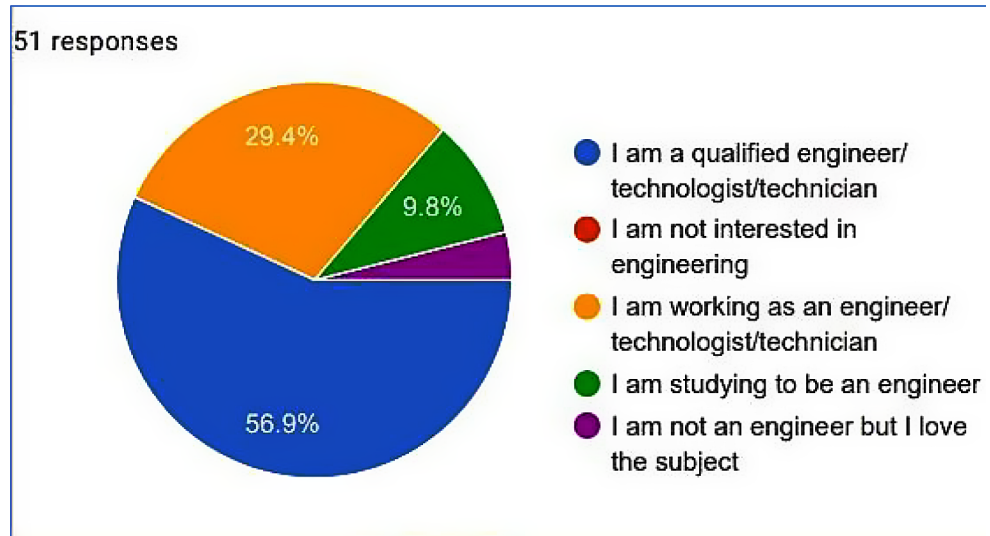


Fig. 2 Limiting factors to choice of study

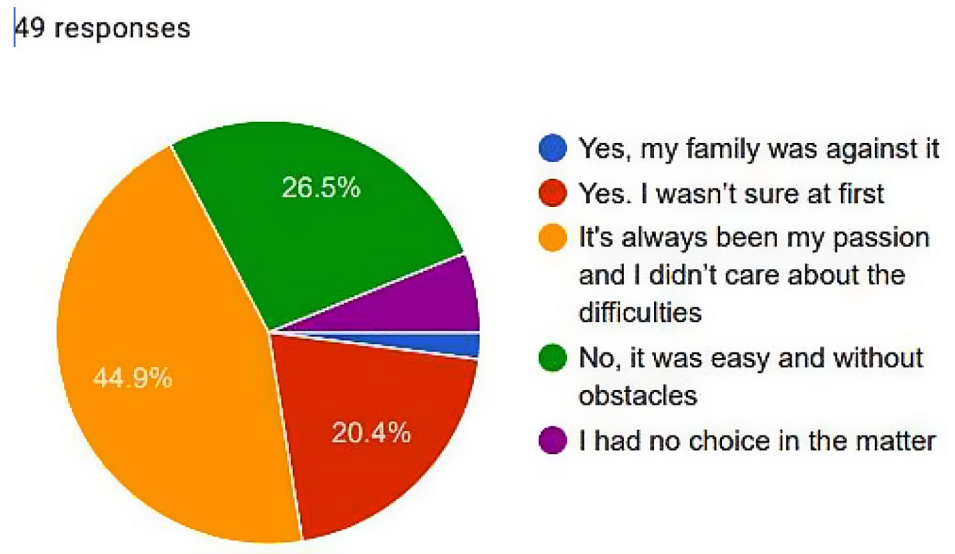
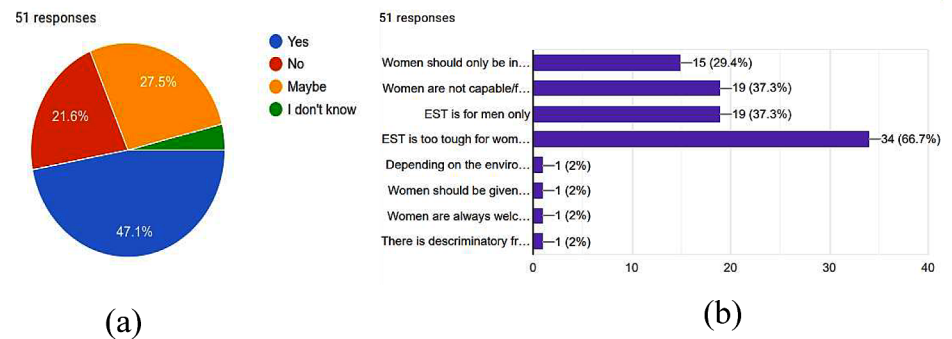


Fig. 3 (a) Lingering issues of biases against women in EST **(b)** Reasons for biases



On the issue of biases against women in EST, we confirmed from 47.1% of respondents that there are still lingering issues which are yet to be properly tackled. While 27.5% of respondents thought there probably were some sort of

prejudice against women, only 21.6% of respondents categorically stated that no prejudices existed against women (see Fig. 3(a)). One confirmed reason given for this prejudice is that women seem to keep or shy away from engineering

jobs that have a strong link with practical hands-on tasks and a fair amount of technical content (41.2% respondents agreed and 29.4% choose maybe). The major prejudice recorded by 66.7% of respondents for women is that EST is too tough for women. Other significant prejudices captured from the survey included a general assessment of women as being incapable or unfamiliar with EST-related fields or tasks (37.3%); that EST is for men only (37.3%); and that women should be completely limited to the humanities (29.4%) (see Fig. 3(b)). Some other reasons given revolved around women not feeling secure in engineering jobs:

“Some women are not sure of themselves”, Nigeria, 26/02/2022,

and for having difficulties combining family obligations with such types of demanding jobs:

“Women are preoccupied with other aspects of life aside career, such as family and life obligations, and it becomes difficult at times for some of them to bridge the gap between these two extremes without any external support” (Nigeria, 26/02/2022).

One respondent explains that women should be supported in this and not discouraged:

“Women should be given help through support programs to encourage them on the need to remain focused and determined no matter what confrontation they might encounter in the study of EST; with these, they become motivated to bring out the best in themselves since practically, a lot of them are fully endowed with potentials that will be very beneficial to industries and the general field of learning at large” (Nigeria, 26/02/2022).

Overall, our results show that 41.2% of women claimed to have suffered prejudices, 33.2% of respondents reported having witnessed prejudices against women, even by other

women, while 45.1% of respondents declared having seen male colleagues show prejudices against women. A smaller number of respondents (15.7%) reported not having ever witnessed any bias towards women. To identify the origins of prejudices experienced by women in EST, respondents were asked to name specific categories of people who believed that women should mainly be interested in non-EST fields, going by personal experience. 60.8% of respondents declared that this is a belief held by the general society, 29.4% said it was a belief held only by men, while 17.6% responded that this belief was only held by women themselves. A few respondents (11.8%), however, reported that this view was only held by some colleagues in the engineering profession. These results are presented in Fig. 4. We were unable to uncover whether the engineering professionals being referred to here were predominantly male or female because the survey was not set up to capture this additional detail.

3.2 Maintenance

In the Maintenance section, our intention was to deepen the importance of maintenance tasks in relation to MDs for the local personnel working in hospitals. Almost 40% of respondents admitted having an internal service of BMETs. Furthermore, 37.3% of respondents declared that in their work environment, maintenance of MDs is done as indicated by the manufacturers or standards; 17.6% were vague about the regularity of maintenance tasks and only reported their respective maintenance schedules as happening quite often (see Fig. 5(a)), while 23.5% submitted that maintenance tasks were only carried out when the MDs developed a fault (i.e., corrective maintenance). Regrettably, the remaining 21.6% of respondents reported that maintenance tasks were rarely or never carried out (Fig. 5(b)). Furthermore, we observed that maintenance is perceived as a man job by 21.6% of respondents, a particularly hard work by 9.8%, and degrading by 4% - totalling 35.4% of all respondents, thus suggesting that our initial idea of the research is probable. Happily, however, more than half of all respondents

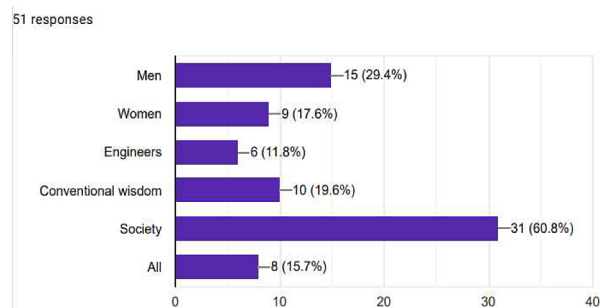
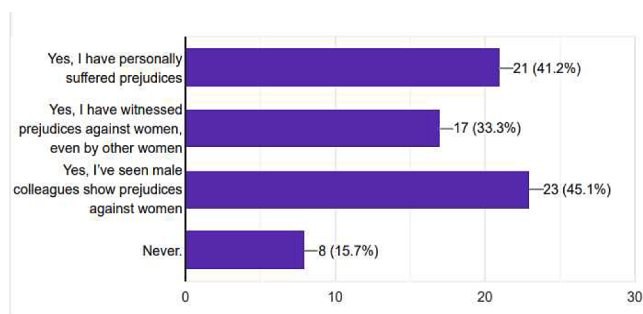
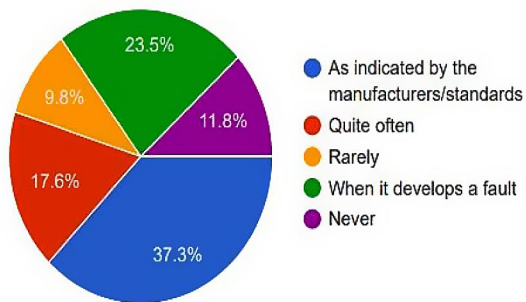


Fig. 4 More details about prejudices against women in EST

51 responses



51 responses

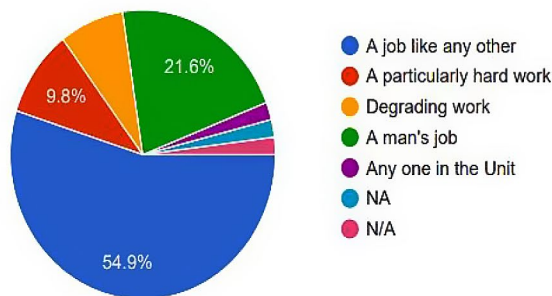
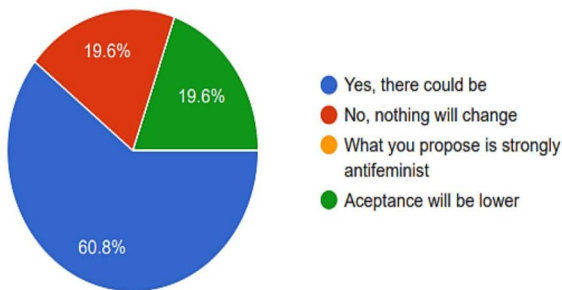


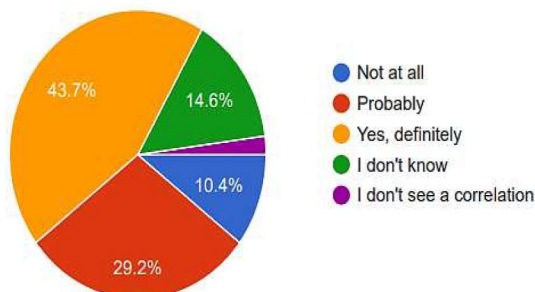
Fig. 5 (a) Frequency of maintenance of MDs (b) Perception of Maintenance jobs

51 responses



(a)

48 responses



(b)

Fig. 6 (a) Women taking the leadership in maintenance jobs (b) Women identifying with maintenance jobs

confirmed that maintenance tasks were just like any other job that needed to be done.

These results made us to propose a parallelism between the maintenance of MDs and maintenance tasks carried out in the house. It is worth noting here that most respondents confirmed many of our initial observations such as the disregard or underestimation of the importance of maintenance of MDs and similarities with maintenance tasks usually performed in the house by women (52.9% of respondents confirmed this similarity while 23.5% agreed to a probable hypothesis of *parallelism*). To the question, “*is it possible that men do not want to take up maintenance jobs at work because they are accustomed to the local culture where women are assigned this role at home?*”, 17.6% of respondent said yes; the same percentage said maybe, while 31.4% responded that they did not know since they had never thought about it. The remaining respondents however were not in agreement. However, most respondents agreed that if women would take leadership roles in the maintenance of MDs, it would lead to a greater involvement of women and acceptance by their male colleagues (60.8%) (see Fig. 6(a)),

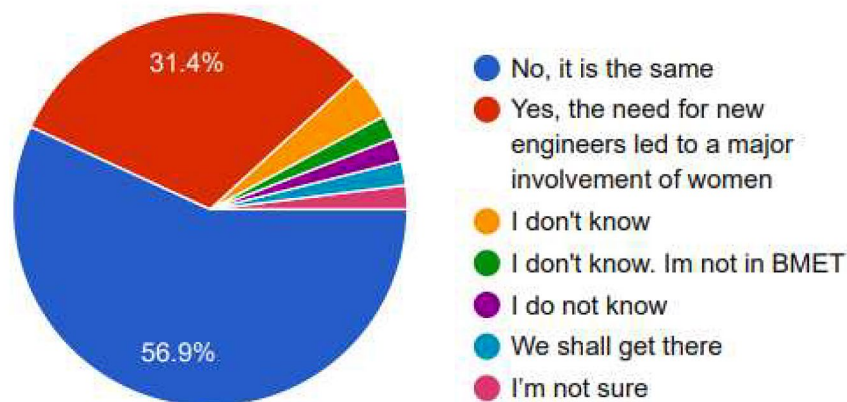
as well as recognition of maintenance related tasks (42.9% - yes; 32.7% - maybe). Similarly, there seemed to be a common agreement that assigning women to specific roles in the maintenance of MDs would not be so far from the socio-cultural common idea of women being responsible for the house and family, thus providing a means of socially recognising women in a role that is typically considered for male BMETs (43.7% - yes, 29.2% - probably) (see Fig. 6(b)).

3.3 COVID-19 pandemic

In the fourth section of the survey, we focused on issues relating to the COVID-19 pandemic because firstly, it would not have been appropriate to neglect such an event, and secondly, we wanted to understand if the much-reported shortage of staff had resulted in a greater involvement of women as BMETs in SSA hospitals. 56.9% of respondents submitted that not much had changed in the condition of female BMETs since the advent of the pandemic (see Fig. 7). However, a lower percentage of respondents (31.4%) acceded to the fact that the need for new engineers led to a major

Fig. 7 Effect of shortage of staff on women's involvement in maintenance as BMETs in SSA hospitals during COVID-19

51 responses



involvement of women. Besides, 45.1% of respondents declared that the importance of maintenance of MDs has significantly increased because of the COVID-19 pandemic, and that this will possibly lead to a gradual increase in the employment of women as BMETs:

“The inclusion awareness is just coming up” (Nigeria, 25/02/2022).

Yet, the same percentage (45.1%) of respondents stated that the maintenance pattern remained unchanged. One respondent in particular argued that it had diminished during this period even though there was a greater understanding of its relevance:

“Due to restrictions on travel, the frequency of visiting facilities to maintain devices has reduced despite people understanding its relevance.” (Uganda, 14/03/2022).

It is worth underlining here that a very small percentage (13%) of respondents declared that the need for more BME professionals during the pandemic correspondingly caused an increase in the number of women in maintenance roles. The majority (49%) however stated that the situation remained the same as before, or only admitted minute changes in the composition of BMETs taking on maintenance roles. The number of men filling up this role was still assessed to be greater by 27.5% of respondents. With reference to the feedback received from respondents, 87% showed their appreciation for the effort the authors had put into the study to increase the visibility of women in BMET leadership roles.

At the end of the survey, respondents were encouraged to provide further comments where relevant, and two of these

in particular were of particular interest. The first was about BMETs in general, and confirmed the need to strengthen the role and job definition of BMETs working in hospitals for the effectiveness of MDs and patient safety:

“Unemployment of BMETs is a great worry in Ghana” (Ghana, 19/03/2022).

The second comment reports an interesting episode of gender bias experienced by one of the respondents:

“With relation to me experiencing prejudice whilst studying engineering; the situation happened in a group project where I was the only girl. The task was to simulate a wind turbine using MATLAB. During the first meeting when tasks were delegated, it was suggested that I make a poster of the wind turbine displaying all the facts because I could make it pretty, but this wasn't even a requirement on the brief!! I felt as if they assumed I wasn't capable to aid in the simulation and they tried to give me a made-up task to keep me busy: ([obviously, I stood up for myself and refused to do that and ended up helping with the simulation]” (Nigeria, 16/03/2022).

4 Discussion

This study helped to explore the underlying issues surrounding the perception of women in EST in SSA. In the different sections of this paper, we deepened various aspects of the topic, starting from the general interest of women in EST, all the way to focusing on existing biases. As described in the first section, women seem to be very interested and passionate about EST fields., It was remarkable to see that many

of our female respondents had been prepared to overcome every limitation in pursuing their preferred course of study. The major problem seemed to occur in the transition from study to work, as only a few succeeded in finding employment. This lack of employment seems typical for women, and the survey unearthed some of the reasons behind this. Typically, these can all be linked to existing prejudices against women in EST, based on underlying conventional perceptions such as women not being familiar with technical/practical tasks, or preferring courses in the humanities and social sciences, or even that they would have difficulty in combining family and work. One key discovery we made is not so much how a woman is perceived, where most people believe that women should prioritize family over their career or preferably adopt a career pathway in the liberal arts, but that women themselves may have unwittingly introjected such patterns of thought (which may generally result in insecurity and lack of confidence), leading women to believe that they have to overcome insurmountable obstacles to excel in science or engineering related courses. One of the ways to effectively dismantle this distorted self-perception is to institute mentoring and training programs that will seek to re-establish the woman's confidence in herself and in her abilities.

In addition to conventional opinions and the woman's perception of herself, the survey also brought to light some evidence of prejudices against women in the workplace. For example, a very high percentage of women said that they had experienced some sort of prejudice or seen prejudicial behaviour against other women. This confirms the fact that gender bias exists for women, which in turn affects their choice of studying EST-related subjects and also impacts on employment opportunities. The fact that women are also assigned the major responsibility of taking care of the home front also plays out as a negative factor in increasing the number of women in EST. This is because of the perception that a job in the EST fields may be more demanding and may take away from the time needed to take care of the family.

Research on the impact of patriarchy and patriarchal norms on women's work-life balance in SSA societies is scarce. Patriarchal societies tend to be organised based on gender, and the construct is embedded in the culture. Male dominance of and excessive subordination of females, domestic and gender-based division of labour, and higher patriarchal trends among men are the ingredients of a patriarchal society. Women's aspirations to achieve work-life balance in the global south are often frustrated by patriarchal norms, which are deeply ingrained in the culture. These issues make the achievement of work-life balance difficult for women as noted by Adisa et al. [17]. Historically, patriarchal societies assign women to the role of taking care of

the *maintenance* of the family and home. Relating this to the work designations of BMETs, it is clear that regular maintenance practices can guarantee longer life and safer use of MDs in hospitals.

As seen in Sect. 3.2, it would appear that a kind of prejudice also exists against maintenance tasks as they are considered degrading for BMETs. This leads to a gross underestimation of the much-needed MD maintenance practices, which (in many cases) are not even performed at all. From these observations, we proposed a *parallelism hypothesis* that links the attitude of men to maintenance tasks at home to their disregard for carrying out painstaking maintenance schedules in hospital settings. Similarly, we tried to understand whether women, who are traditionally assigned maintenance tasks at home, would consider taking the lead in the maintenance of MDs, and if men would find this acceptable. We observed that both genders were quite positive towards this suggestion. Nevertheless, we are conscious of the fact that this reasoning could be misunderstood to be anti-feminist by some and interpreted to mean that women are again being relegated to their traditional subordinate roles by assigning them to tasks that men would normally shy away from. Our intention with this projection is to identify a field of specialization for women that could restore their confidence, recognize their leadership in specific roles, and improve their employability. Ultimately, we believe that if this sort of change is adopted in SSA, it could potentially contribute to great improvements in maintenance practices in terms of continuity and planning since maintenance tasks are not only essential to promoting the safety and effectiveness of MDs, but also, from a philosophical point of view, are worthy of painstaking human and capital investments because of the proven long-term benefits.

Maintenance tasks can be likened to Heidegger's concept of care (in *German Sorge*) of the things nearest to us (in *German Bersorgen*). Care, in *German Sorge*, is the backbone of existence; it implies having to do with something, i.e., looking after it. It projects a form of concern and *affectivity* that represents the *being-in-the-world* of the existing [26]. This form of caring, (i.e., maintenance), is not an imposed and degrading obligation, but a familiar activity to the woman, who, in taking on such responsibilities, can become better recognized and acknowledged by the society for the specialty and importance of such roles and tasks. By redefining maintenance tasks for women, two possible results are suggested: (a) the woman is better positioned to fill leadership roles in EST fields and (b) maintenance practices regain its overall importance in prolonging the lifespan of MDs and other relevant equipment.

Over time, the HHF has consistently shown good performance by helping to propose solutions that aim to overcome inherent criticalities and biases, thus tending towards

a universally acceptable perspective that incorporates the importance of sociocultural particularisms. In this study, we proposed a solution that involves and respects the traditional role of women in caring for the home, which could potentially reduce unrespectful prejudices and degradation of women in workplaces. Thus, by adopting this sociological model, and given the right opportunities, women can successfully fulfil leadership roles in EST-related fields and greatly contribute towards improving maintenance of MDs in SSA.

The framework serves as an interpretative lens (i.e., hermeneutic) that can inductively (i.e., heuristically) enable consideration of the peculiarities of different contexts, which may involve subjective and objective factors, and 'by design', provide answers to local contextual needs. By this, we do not refer to the doctrine of relativism, which tends towards the philosophical view that no absolute truth exists, but propounds that knowledge, truth, and morality are relative only to the beliefs of particular individuals, cultures, society, or historical context. Rather, the HHF tends towards a common perspective of universalism, which expresses views about the shared characteristics of all peoples assessed from historical antecedents and can be considered as mutable. This essentially means accepting the fact that the context in which a need is being considered is not static, and thus prevents proposing definitive solutions. More specifically, the framework emphasises the importance of learning by doing and trying to provide answers to local exigencies with reference to the universality of rights. This approach attempts to hold together the particularism of each context and the universality of principles and human capabilities as expounded by the philosopher M. Nussbaum and the economist A. Sen [27], and could lead to the reframing of democracy [28] through interdisciplinary interactions between political, socio-anthropological, ethical and technological aspects. Some advantages that become immediately apparent with using the framework include:

- Increase in the universality of medical device regulations (MDRs).
- Increased access to human rights.
- Increased focus on vulnerable and young people.
- Addressing local needs with the 'by design' approach for ethics and BME.
- Transforming policy making with frugal approaches.
- Creation of a multidisciplinary workforce.

In the fourth section of the study, we tried to understand whether the COVID-19 pandemic led to an increased need for BMET staff and experts, thus allowing a greater involvement of women in related tasks. Sadly, we did not observe any remarkable difference in the demand for BMETs before

and during the pandemic. We believe that for any real change to take place, there must first be a major paradigm shift from the status quo. Therefore, developing and implementing programs and activities to train women in seeing the potential in themselves based on theories such as the parallelism model proposed in this survey might well be the gamechanger in encouraging women at different levels of accomplishments to pursue their passion and increase their self-confidence. We are of the opinion that government involvement in awareness campaigns to sensitize the public about the inbuilt capabilities of women to succeed in this area of endeavour that may be more natural to them than men is necessary to realize this change of mindset or hermeneutical perspective. Specifically, this would require improving general education on the topic of women in EST, supporting programs to encourage women in EST, empowering societies of women in EST to challenge the status quo, focusing on maintenance-related topics, and disseminating the results of studies of this nature.

5 Conclusion

In this paper, we explored innovative MD maintenance strategies that are fast becoming the norm in more advanced societies, which could impact positively on maintenance practices in LRSs such as in SSA. AR and VR have great potential to overcome some of the difficulties associated with BMETs maintaining very complex or new medical devices by providing the much-needed maintenance protocols and training. Besides, integrating IoT technology with AI can allow for continuous learning and improvement of predictive maintenance systems that can optimize equipment availability, reduce adverse events, and enhance patient safety. Also, we present the results of a sociological investigation aimed at mapping a realistic image of women in EST roles in LRSs, (particularly in SSA), to identify existing biases, with a specific focus on the BMETs' role in the area of MD maintenance. Mainly, we were able to pinpoint some gender biases against women in EST as well as some patriarchal models of gender roles. Some of the authors of this papers are currently validating a bottom-up approach model, i.e., the hermeneutic heuristic approach, which allows solutions that embrace sociocultural perspectives within the context of the universalism of rights. To project new perceptions of women in EST, we concluded from the submissions of our survey respondents that a positive change in the image of women in EST fields was more likely to happen if local sociocultural perspectives and respect for human rights and dignity are taken into consideration. The adoption of the proposed parallelism between domestic maintenance tasks, which is dominated

by women, and the maintenance of MDs in hospitals, which is neglected and mainly considered exclusive to men, could well be a possible route to reshaping perceptions of women as BMETs in hospitals. Allowing women to take leadership roles in maintenance-specific tasks, could provide a means of transforming effortlessly into their traditional roles, while also changing the landscape of MD maintenance in hospitals to improve their effectiveness and safety. We believe this approach will help women to find their own space and arrive at a point of self-determination that will allow them to exercise better leadership skills at work, thus emphasizing their familiarity with EST and other techno-practical tasks. It is our hope that in this way, a new perception of women in EST in SSA, which is comprehensible and compatible with the social environment, and introjects positively in the local mindset, can be fostered. In future work, we hope to extend this study to a wider group (e.g., at a global level), and also incorporate study elements that will allow us to derive far-reaching conclusions about harmonisation between genders. Moreover, armed with data gathered from this study, we plan to develop awareness-raising programs in partnership with specific local associations in SSA to address this malaise. The expected outcomes of these activities would be to increase the number of women accessing scientific studies in these settings, minimise gender bias, and ultimately increase medical device maintenance practices in SSA hospitals.

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Data availability The authors confirm that all data generated or analyzed during the course of this study (i.e., survey questions, survey results and statistics, expanded answers to survey questions) are anonymized and included as supplementary information in this published

article.

Declarations

Ethics approval The methodology for this study was approved by the Human Research Ethics committee of the University of Warwick (Ethics approval number: REGO-2018-2283).

Competing interests The Authors declare that there is no conflict of interest.

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