# Paving the Path: Empowering Women in STEM From University to Industry

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***Abstract*— The recent digital transformation of higher education underscores the crucial role of STEM disciplines in addressing real-world challenges, emphasizing the urgent need for problem-solving skills, creativity, and diversity within the STEM student community. Despite growing awareness of the gender disparity in STEM professions, women remain underrepresented in these fields. This paper conducts a comprehensive study delving into the determinants influencing the decision to pursue a STEM degree and the challenges faced during STEM education. Through survey data analysis, the research explores actionable mechanisms to enhance the presence of women in STEM subjects and support their career progression. The study not only identifies obstacles but also formulates a set of recommendations to establish a robust support system for women in STEM. These recommendations aim to foster their academic retention, facilitate continuous professional development, and contribute to narrowing the gender gap in STEM occupations. By addressing the root causes and proposing concrete solutions, this research seeks to contribute to a more inclusive and equitable STEM landscape, fostering an environment where women can thrive and make significant contributions to the ever-evolving field of science and technology. Furthermore, this research serves as a call to action for institutions, policymakers, and stakeholders to collectively champion initiatives that empower and propel women to excel in STEM fields.**

**Keywords—women in STEM, Gender Gap, STEM, Higher Education**

## I. Introduction

Over the years, the underrepresentation of women in STEM (Science, Technology, Engineering, and Mathematics) degrees has been a persistent concern and has drawn the attention of many scholars and educators who dedicated considerable attention to addressing this issue, focusing on women's enrolment and degree attainment in STEM fields. Despite concerted efforts, women continue to face underrepresentation both in higher STEM education and the workforce [1]. According to the report on the STEM workforce published by the National Center for Science and Engineering Statistics in 2021, about one-third of those employed in STEM occupations were women [2]. This represents an increase of 3% as compared to 2011. While there has been a modest increase in female graduates in STEM degrees such as biology, the numbers remain disproportionately low in fields like engineering and the physical sciences [3].

As a commitment to advancing diversity in STEM, many educational institutions explored diversity-focused STEM intervention programs (SIP). Palid et al. [4] compared these interventions across higher education, and their findings suggest that multi-component interventions, fostering a welcoming environment and emphasizing success for minoritized students, show promise in addressing institutional shortcomings for diversity, equity, and inclusion in STEM. However, the study emphasizes the need for more rigorous quantitative research to assess the effectiveness of individual SIP components.

Despite the continuous evidence demonstrating the positive influence of gender diversity on innovation performance, especially in STEM fields, women pursuing careers in STEM still encounter challenges in sustaining their professional paths within traditionally male-dominated STEM industries. The study conducted by Kurmankulov et al. [5] emphasizes the influence of the presence and support of women professionals in academic and social environments on female STEM students' awareness of career challenges. Surprisingly, the study revealed that increased awareness about gender inequality can lead to an early exit from STEM careers. Thus, the authors suggest that the gender-related public awareness campaigns should be coupled with palliative measures to avoid inadvertently accelerating the "leaky pipeline phenomenon" in STEM. Even though the attention on attracting women into higher education STEM programmes is substantial, once enrolled, there is a lack of support and mentorship, leading to a significant dropout of women from university or a shift to alternative career paths [6].

Recognizing the need for more rigorous research in this area, our study seeks to bridge the gap by understanding the challenges faced by women studying STEM subjects at the university level. Through data collected from questionnaires distributed among female students in the Faculty of Science and Technology at Middlesex University in London, this research endeavors to contribute valuable insights that will facilitate the progress, transition, and retention of women in STEM professional careers. Leveraging insights gained from this study and existing literature, our objective is to formulate an inclusive support system tailored to address the unique needs and challenges encountered by women pursuing STEM degrees. This proposed support system aims not only to foster academic success but also to facilitate a seamless transition from university to the professional landscape, ensuring sustained and rewarding careers in STEM industries.

This paper is organized as follows. Section II presents a comprehensive literature review. Section III details the methodology used for data collection. Section IV introduces the results analysis and discussions. Section V compiles a set of recommendations to enable a robust support system for

women in STEM. Finally, Section VI summarizes the conclusions along with suggestions for future research.

## II. Literature review

STEM disciplines are critical for fostering innovation and supporting the ever-expanding realm of technology [7]. Despite this, STEM has been widely criticized for its insufficient representation of women, who remain a minority among STEM degree holders [3]. In this context, this section delves into the multi-faceted landscape of support mechanisms available to women pursuing careers in STEM. Spanning crucial stages of their professional journey, the related works are classified into three categories: (1) pre-university or outreach initiatives; (2) during university studies; and (3) post-university for professional women working in STEM careers. This comprehensive examination aims to uncover a diverse array of initiatives, challenges, and interventions aimed at fostering gender equity in STEM fields. By scrutinizing the existing body of literature, this review seeks to illuminate the evolving strategies and gaps in support systems, offering insights into the intricate dynamics that influence women's trajectories in STEM professions.

Bottia et al. [3] investigate the impact of high school faculty gender composition, emphasizing the role of female math and science teachers. The results suggest that a higher percentage of these teachers is linked to an increased probability of young women, particularly those skilled in mathematics, choosing STEM majors. The study suggests this influence counters gender stereotypes, fostering a more supportive STEM environment. Highlighting the importance of early education, the authors advocate for interventions challenging stereotypes to boost female participation in STEM fields. Other studies have also emphasized the importance of female role models, such as female teachers, as motivators for female students to enter STEM fields [7].

Numerous factors influencing female students' pursuit of STEM degrees have been identified in the exiting literature. A recent retrospective study found that having STEM teachers as mentors and higher levels of parental education increased the likelihood of female STEM students pursuing a degree in STEM [8]. Additionally, female students that participated in research activities during their high school education positively correlated with STEM degree attainment, although this finding is somewhat limited by reliance on retrospective data which is likely to increase recall bias.

He et al. [9] tried to understand the underrepresentation of females in STEM subjects through an exploratory study of female high school students in China. The study revealed that traditional parental expectations for daughters steer them toward caring roles like nursing, teaching, and civil service. However, this cultural context may not be universally applicable. Interestingly, it was further suggested that female graduates were found to be more likely to work in lower status 'caring' roles than their male peers, potentially contributing to the lower engagement of females in STEM degrees [10].

Literature indicates gender-based variations in STEM preferences and abilities. Female students often show greater interest in science but may exhibit less inclination towards mathematics, with engineering being less enjoyed by them [11]. Recent trends show increased female participation in biological sciences, medicine, and psychology, underscoring the importance of targeted efforts to enhance the appeal of all STEM subjects to female students [10]. Burgos-Lopez et al. [12] tackle gender discrimination in Latin America, stressing its ethical concerns. The study advocates for early intervention in childhood education, emphasizing the importance of positive gender attitudes. Notably, it suggests engaging men as advocates in gender equality initiatives to effectively reduce the gender gap. The research outlines strategies for creating safe, equitable STEM environments for women, supporting their professional growth, and ensuring fair compensation.

In [13] the author identified the importance of extending pre-university outreach programs beyond their conclusion by extending invitation to school students to visit technology institutions, exposing them to lab facilities, and providing essential information about admission requirements, financial aid, and personalized mentoring. These have been identified as crucial elements that contribute to building curiosity, creativity, and impactful outreach among young learners.

The study conducted by Hernandez et al. [15] finds that mentoring has consistently shown benefits for female students, enhancing self-belief, motivation, and persistence, ultimately leading to long-term achievements. Perna et al. [16] examined how Spelman College, a historically Black women's college, fosters the success of African American women in STEM fields. The findings highlight Spelman's role in promoting academic and psychological readiness, emphasizing the importance of institutional commitment and peer relationships. While acknowledging Spelman's success, the study identifies persistent challenges, particularly financial difficulties, and suggests implications for policy and practice, including the need for culturally relevant pedagogy and financial aid programs. Redmond et al. [17] examined the outcomes of an e-mentoring initiative, the Aiming for a Brighter Future Program, part of the GoWEST (Go Women in Engineering, Science and Technology) project, supporting females in STEM in remote areas. The program, involving mentors from STEM industries, targeted high school students, university students, and women re-entering STEM. Utilizing various communication means, the study outlines the program's five phases: planning, promotion, preparation, program support, and conclusion with evaluation. Results emphasize e-mentoring's effectiveness in overcoming geographic barriers, promoting peer support, reducing attrition, and fostering STEM interest among women.

Avolio et al. [18] conducted a phenomenological study on professional development barriers for women in STEM. Individual, family, and societal factors, including self-concept, family demands, gender stereotypes, and economic-related issues, were identified. The study proposes a conceptual framework of 12 interrelated elements affecting women in STEM. Blaique et al. [19] explored coping self-efficacy, protean career attitudes, and career identity in Middle Eastern women in STEM. Protean attitudes positively impact career identity, with coping self-efficacy being a key predictor. The findings highlight cognitive factors' importance, offering insights for future research and practical implications for career counselling and policymaking. Similarly, Conrad et al. [20] investigated women's underrepresentation in STEM, focusing on engineering. Barriers, including flexibility and work-life balance, were identified across STEM disciplines. Engineers face additional challenges like lack of interest in the job. The study emphasizes the need for inclusive work cultures, family support, mentorship, and gender-bias training to enhance women's persistence in STEM, with implications for employers and institutions to narrow the gender gap.

An overview of relevant related works from each of the three categories is provided in Table I.

TABLE I. OVERVIEW OF RELEVANT LITERATURE

| Category | Ref. | Target Groups | Methodology | Main Findings | Limitations |
|---|---|---|---|---|---|
| Outreach (pre-University) | [3] | Public school graduates | North Carolina Roots of STEM Success dataset containing longitudinal information on the academic performance and scholastic experiences of 2004 North Carolina public school graduates. Sample size of 12,550 students coming from about 270 high schools. | Women who attend high schools with a higher proportion of female math and science teachers are more likely to declare and to graduate with a STEM major in college. | The findings may not be generalizable to students in different geographic regions or educational systems. |
| | [7] | Female students studying in the 3rd and 4th years of science education in Turkey. | Convenience sampling method was used, collecting data from 309 female students though an online questionnaire. The data was collected during the spring term of the 2020 – 2021 academic year, over a 4-week period. | It has been found that female science education college students' motivations towards STEM fields differ according to four variables: "father's education level", "having received STEM education", "having participated in STEM activities", and "having a role model working in a STEM field". | The study group was deliberately limited to the third- and fourth-year female students of science education college who already have some STEM awareness. |
| | [8] | High school experiences of students graduating from selective high schools | Data collected by email as part of a retrospective survey (4-6 years after high school graduation, 2004-2007 graduates) study funded by the National Science Foundation. Survey respondents consisted of 1797 females. | Parental educational level and having STEM teachers as mentors predicted female students' research participation in high school, which in turn increased the likelihood of female students' attaining an undergraduate STEM degree. | Potential recall bias, one item for each (parent, teachers and peers- e.g did not capture influence from either the mother or father) |
| Support during University studies | [15] | First and second year female STEM students at one of seven four-year universities in the Colorado or the Carolinas. | Data collection began in the fall semester of 2015 with a brief matching survey. All students that met the inclusion criteria were invited to participate in an informal mentoring Programme. A follow-up survey data collection was completed in the spring of 2016. | The study found that mentoring support from faculty members benefits early undergraduate women by strengthening their scientific identity, but did not observe benefits from graduate student and peers mentoring support | The data follows changes in college women's experiences across a total of six months out of a single academic year, limiting insights into long-term effects. |
| | [16] | Black female students at Spelman College, faculty members and administrators. | Five focus groups interviews (65min/focus group, audio and video recorded and transcribed), three with students and two with faculty and administrators, taking place at Spelman College. The study involved 19 Black women students majoring in STEM, three faculty members and five administrators having varying roles. | The findings from this study point to the potential benefits of adapting STEM curricula and instructional practices to promote students' achievement in STEM courses, as well as their confidence in their ability to succeed in STEM fields. | The study relies on data from a relatively small number of students, faculty, and administrators at just one institution. |
| | [17] | High school and university students as well as women returning to STEM careers. | Four sources of data collection: a pre-mentoring online survey (23 participants), a post-mentoring online survey (15 participants), participant interviews (6 participants, 30min via phone or Skype), and an anecdotal diary kept by the project facilitator. The study consists of 24 one-on-one mentoring relationships over a 10-month period. Three mentoring relationships withdrew mid-program. | E-mentoring can increase peer support and professional sharing. There is also evidence that e-mentoring in these fields can help to reduce attrition of women in the field and to boost interest and enthusiasm for studying and seeking employment in STEM disciplines | Small scale study, results might be subjective and hard to generalize. Potential bias in responses. |
| Professional Journey (post-University) | [18] | Professional women (not in academia) in STEM careers in Peru. | Qualitative phenomenological method was used, with in-depth semi-structured interviews (approx. 45 min) being conducted. 15 women in professional STEM careers participated voluntarily. | The women who participated in this study said that stereotypes affect social perceptions about their abilities, as their intellectual or work performance is questioned or roles are assigned to them within STEM-related fields that are more linked with stereotypes about women, like the idea about them being more orderly. | Focus on participants' perceptions and exclusion of intersectional elements like race and class |
| | [19] | Women who have worked in STEM industries for at least two years in the Middle East region | Questionnaire survey collecting data from 482 women professionals in STEM. | Women who perceive themselves as capable of coping with the challenges and barriers of working in STEM will be able to build a clear and strong sense of their career identity. | The findings may not be generalizable to women in STEM careers in different geographic regions. Potential bias in responses. |
| | [20] | Women working in STEM | Online questionnaire distributed via email and social media postings to STEM support groups for women. A total of 118 women in STEM careers completed the survey during Fall 2019. | The top challenges reported by women in STEM include difficulties in achieving work/life balance, gender bias or discrimination, and high stress levels. | Small sample of participants engaged in online or company-driven support systems. Potential bias in responses. |

## III. Methodology

To be able to understand the factors that shape female students' decision to enrol into a STEM degree, the challenges faced while pursuing their STEM degree, as well as any sexism related issues they might have faced, we conducted a case study within the Faculty of Science and Technology, at Middlesex University in London. The case study is based on an anonymous questionnaire that was designed in SurveyMonkey and approved by the Faculty's Computer Science Department's Research Ethics Committee. The questionnaire consists of 15 relevant questions spread across four parts: (1) background and pre-university education; (2) initiatives and factors that influenced the decision to enrol onto a STEM degree; (3) current STEM degree and challenges faced including sexism; (4) current and further support required to succeed in their STEM degree. Invitations to participate in the questionnaire were extended to the entire population of 2162 female students (undergraduate and postgraduate), enrolled in the academic year 2022-2023, within the faculty through official email. The questionnaire was open from 3rd to 16th of July 2023. Participants were presented with a participant information sheet and given the option to consent to participation. Choosing 'No' resulted in survey closure. Contact information for the researchers involved in the study, was shared with all participants, encouraging them to address any concerns or questions. The questions were optional, allowing participants the choice of not answering specific questions if they wished. A total of 317 responses were received, encompassing both partially and fully completed questionnaires. Despite a substantial return rate, 82 incomplete questionnaires were considered defective due to a very large number of unanswered questions. After this initial filtering 235 valid responses were selected for further analysis. On average, respondents spent 8 minutes completing the questionnaire.

## IV. Results and Discussions

This section presents the results of the questionnaire and comprehensive discussions are provided. Correlation studies are included, and sentiment analysis is performed on the open-ended questions.

### A. Background and Pre-University Education

The dataset includes participants from various age groups, with a concentration in the 18-24 (52%) and 25-34 (30%) ranges. However, there are few respondents aged 35-44 (12%) and even fewer in the 45 (6%) or over category. There's a mix of ethnicities, suggesting a multicultural sample with White/White British (30%), Asian/Asian British (32%), and Black/African/Caribbean/Black British (22%) being the most frequently mentioned ethnic backgrounds. The Mixed/Multiple ethnic groups represented 8% of the responses while 8% indicated Others including responses like Arab, Turkish Cypriot, Turkish, Hispanic/Latin, White African, White Eastern European, Indian, Middle East, and Iranian. This indicates a diverse group of respondents.

The majority of respondents received their pre-university qualifications in the UK (55%). There is a notable presence of individuals who received their qualifications outside the UK or EU (33%), with specific countries mentioned, such as India, Nigeria, Dominican Republic, Egypt, Pakistan, Sri Lanka, United States, Colombia, Turkey, USA, Australia,

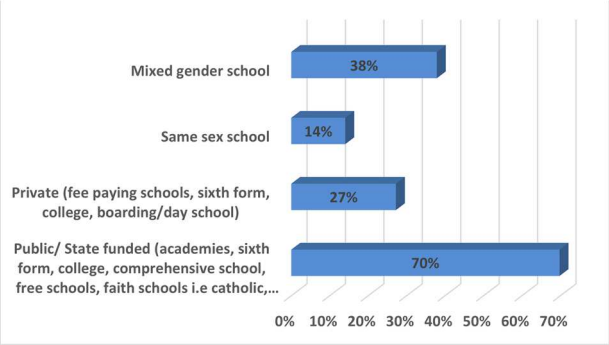


Fig 1. Type of School Attended

Iran, and others. In contrast, only 12% of the participants received their pre-university qualifications in EU.

Our questionnaire also shows that people from various ethnic backgrounds and countries have attended different types of schools, including public, private, same-sex, mixed-gender, and others as illustrated in Fig.1. A significant number of participants attended public schools either with mixed-gender environment or a few with same-sex environment. There is also a notable representation of participants who attended private schools with a mixed-gender environment and a few with same-sex environment. Other forms of schooling were mentioned as well, including homeschooling.

These insights highlight the diversity in the types of schools attended by the participants, encompassing public, private, same-sex, and mixed-gender schools, reflecting a variety of educational experiences and preferences.

### B. Initiatives and Factors of Influence

This section will dwell into the initiatives and factors that contributed to the decision to enrol onto a STEM degree. Fig. 2 captures the responses of the programs and initiatives that inspired participants to enrol onto STEM degrees. Most of the participants mention a variety of influences, such as university open days (33%), work placements/experiences (34%), guest speakers/role models (23%), and career days (18%). The participants that selected Other (24%) were motivated by their own desire to pursue a specific subject or a doctorate. The reasons are diverse, ranging from personal interest and passion to the influence of family members or specific courses. The responses reflect a mix of intrinsic motivations, external exposures, and educational experiences contributing to STEM degree enrolment.

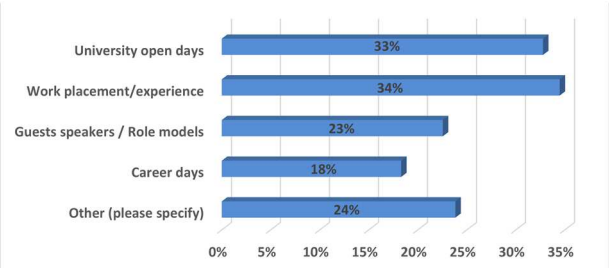


Fig. 2. Initiatives that inspired participants to enrol onto a STEM degree

Interestingly, Keane et al. in [21] underscore the significance of *Career Fairs* held in schools as the most popular means of student engagement. These events effectively connect students with universities or

organizations and are targeting both male and female students. Despite the acknowledged influence of *Career Fairs* on students' career choices, Molnar et al. [22] emphasize that dedicated programmes aimed specifically at female students, such as Women in Technology events, prove valuable in encouraging their enrolment in STEM degrees.

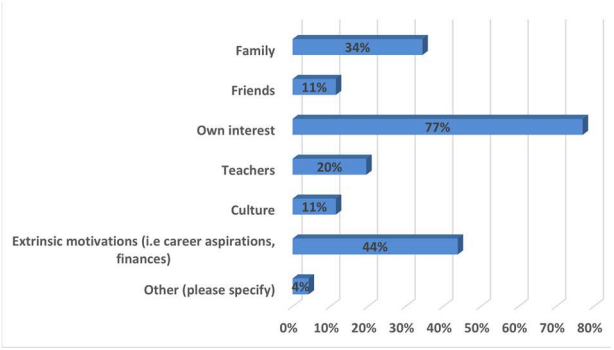


Fig. 3. Factors Influencing the decision to enrol onto a STEM degree.

Fig. 3 illustrates the influencing factors that contributed to the decision to enrol onto a STEM degree. The results show that everyone's decision to pursue a STEM degree is influenced by a unique combination of factors, and these influences can vary greatly from person to person. Own interests and circumstances are the most important drivers of the decision. Family appears to be a significant influence in the decision as it can have various impacts, such as financial support or encouragement. External motivations, such as career prospects and financial considerations, appear to be important factors as well.

The participants were also asked to provide more details about these influences through an open-ended question. The descriptive analysis of the responses reveals a rich tapestry of influences, blending personal passion, familial expectations, societal perceptions, and career aspirations. The decision-making process is often shaped by a combination of these factors, highlighting the multidimensional nature of educational choices in STEM fields. A breakdown of the key themes identified is provided below:

- **Early Interest in STEM:** Many participants expressed an early interest in STEM subjects during their school years. Influences include enjoying math since a young age, playing with computers, and being inspired by sci-fi movies with tech-savvy characters.
- **Family Influence:** Family members, especially parents and grandparents, who pursued STEM careers themselves, played a significant role in influencing career choices. There is a recurring theme of family members having degrees in fields like law, teaching, medicine, and science, influencing the individual to pursue a similar path. Moreover, the expectation to pursue higher education, especially in STEM, was prevalent in families where education was highly valued.
- **Personal Interest and Passion:** Many respondents express a personal interest or passion for the chosen field. Participants expressed specific interests within STEM, such as programming, psychology, engineering, and medical biochemistry. This intrinsic motivation is a powerful driver for academic and career choices. Participants mentioned wanting to understand human behaviour, contribute to well-being, and make a positive impact on society.
- **Career Goals and Financial Considerations:** Career aspirations play a significant role, with mentions of specific career paths like oncology research, medical laboratory scientist, environmental health, and technology-related roles. Financial stability is highlighted as a factor, with some noting the higher pay associated with STEM qualifications.
- **Educational Environment:** Exposure to STEM-related activities during school, including career talks, guest speakers, and engaging teachers, had a positive impact on influencing educational choices. Friends and peers pursuing STEM degrees are mentioned as influences, showcasing the impact of the educational environment on decision-making.
- **Cultural and Societal Expectations:** Cultural and societal expectations are cited by some participants. In some cultures, pursuing science is considered prestigious and a mark of intelligence. The perception that STEM degrees are more respected by society is mentioned by a few individuals.
- **Role Models and Inspirational Figures:** Having role models, inspirational teachers, or family members working in STEM fields has motivated some individuals. Personal experiences with professionals in the field, such as physiotherapists or doctors, have also inspired career choices.
- **Gender and Diversity Initiatives:** Some respondents mention the influence of initiatives promoting STEM for women. The awareness of the need for diversity in STEM fields has inspired individuals to pursue such careers.
- **Social Impact and Helping Others:** The desire to make a positive impact on society and improve health and well-being is a recurring theme. Respondents mention aspirations to contribute to healthcare, environmental management, or public health.

Overall, the responses reflect a diverse range of influences, highlighting the importance of personal passion, family support, role models, and educational experiences in shaping individuals' decisions to pursue STEM degrees.

### *C. Gender Balance across STEM degrees*

The participants' areas of study cover a wide range of disciplines, including psychology, health sciences, engineering, computer science, and more as illustrated by the word cloud in Fig. 4. In terms of level of study, 63% of participants are enrolled onto an undergraduate degree, 29% postgraduate degree and 8% are pursuing a research degree.

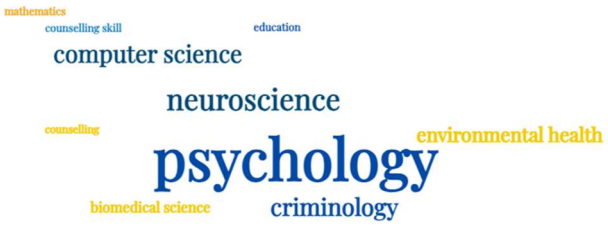


Fig. 4. Areas of study

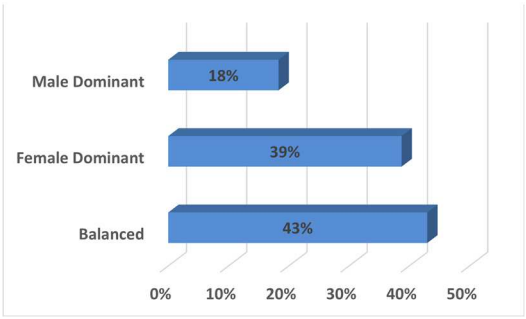


Fig. 5. Reported gender balance across all levels of study

The results also indicate that 43% of participants perceive their courses as gender-balanced, 39% as female-dominant, and 18% as male-dominant, as depicted in Fig. 5. However, it is crucial to delve into the specific courses that respondents are pursuing, as this may shed light on the observed gender balance and the relatively low reporting of male dominance. For example, the Psychology and Neuroscience courses tend to be perceived as female-dominant, courses in Environmental Health and Biomedical Sciences are perceived as balanced, while Computer Science, Information Technology, and Mathematics courses are perceived as male-dominant. It is essential to acknowledge that perceptions of gender balance might be subjective and influenced by individual experiences within each field.

### *D. Challenges Encountered during STEM education*

Participants were asked if they had experienced sexism and were also prompted to outline any other challenges, they had faced during their STEM degrees. Fig. 6 illustrates experiences related to sexism, where 85% of the participants indicated that they did not experience any form of sexism during their STEM degree. This suggests that, at least in their particular educational context, they did not encounter discrimination based on their gender. However, this might also suggest that due to the diverse participant population, they might not be aware that they have been victim of sexism. A recent study [14] revealed a concerning pattern of sexism in STEM degrees, particularly in physics (50%), engineering (30%), and computing (20%). Addressing these issues is crucial for promoting diversity, inclusivity, and equitable opportunities in STEM education. Interviews with women studying STEM revealed that sexism usually involved male peers questioning women's academic capability and ignoring or patronizing them.

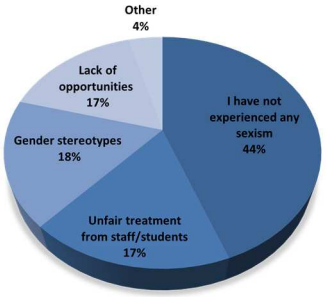


Fig. 6. Sexism experienced.

This aspect is revealed by our survey data as well, where some respondents mention specific instances of sexist comments or assumptions made by male peers or teachers. A few note that male students have made sexist comments towards female students. On average, 33% of participants claimed that they had been treated unfairly, experienced gender stereotypes and a lack of opportunities. Thus, there is a range of responses, from affirmations of no sexism to instances where sexism is acknowledged.

Fig. 7 shows the types of challenges that participants have experienced. These include lack of parental support, negative peer pressure, internal difficulties and other.

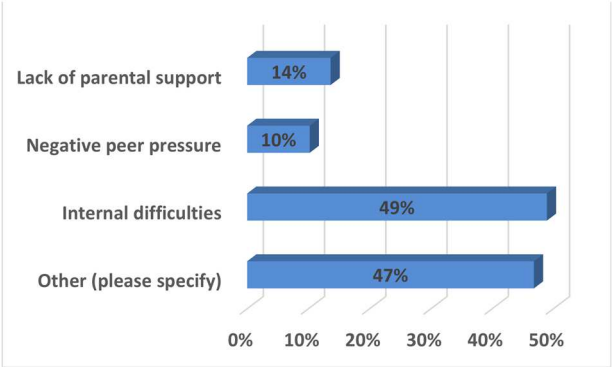


Fig. 7. Challenges experienced.

While some report positive experiences without sexism, others acknowledge challenges, negative peer pressure, financial difficulties, and internal struggles. The responses highlight the need for a nuanced understanding of the experiences of individuals in STEM fields and the importance of addressing various challenges they may face. A significant number of participants cite internal difficulties as a challenge. This is a broad category that could encompass personal struggles, academic pressure, or mental health challenges. Some participants faced difficulties due to a lack of support from their parents, which might include financial support or emotional support. Few participants refer to negative peer pressure, which might involve discouragement or judgment from peers. Participants that selected 'Other' indicated that disability, finances, work-life balance, homesickness etc. were challenges that they faced during their degree. Age related challenges have been mentioned by a few older participants experiencing ageism or a lack of appreciation for their opinions in a predominantly younger student population. Some respondents mentioned societal perceptions of STEM fields, including stereotypes and misunderstandings about what STEM subjects entail. International students faced challenges related to cultural differences and a lack of guidance. In summary, the responses provide a diverse range of challenges faced by the participants, reflecting the multifaceted nature of individuals' experiences in educational and professional settings. These challenges go beyond academic concerns and underscore the importance of holistic support systems in fostering student success.

It is also important to note that participants from various ethnic background differed in the obstacles they faced. Whilst internal difficulties remained high in all the different ethnic backgrounds, students from the Asian/ Asian British ethnicities had the highest reporting of internal difficulties whereas Mixed/ Multiple ethnic groups had the lowest as illustrated in Fig. 8.

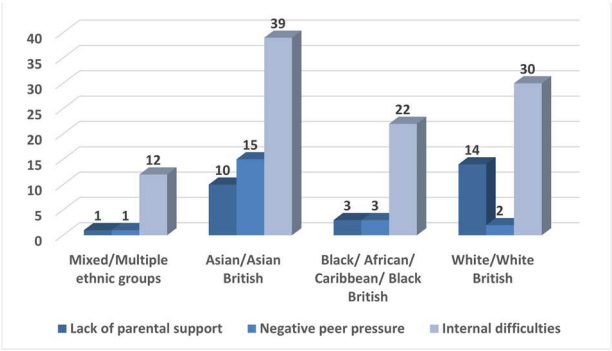


Fig. 8. Challenges faced per ethnic background.

## E. *Support to Succeed*

When asked how supported they feel in their STEM degrees, participants expressed varying levels of perceived support. As illustrated in Fig. 9, most responses fall into the categories of "A moderate amount" and "A lot," suggesting that a significant portion of the participants feel adequately supported in their STEM studies. This is a positive indication of the educational environment's effectiveness in providing support to their female STEM students.

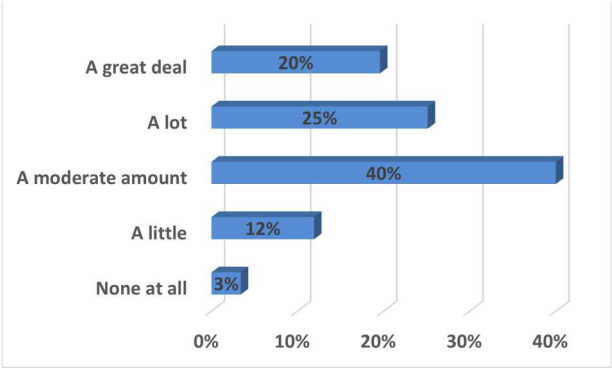


Fig. 9. How supported they feel in their STEM degree

Additionally, exploring a follow-up question regarding the other forms of support required enables us to provide deeper insights into the specific support requirements or areas where improvement is needed. Overall, the dataset suggests that female students in STEM programs are looking for a combination of academic, career, and diversity-related support to enhance their educational experience and prospects in the field.

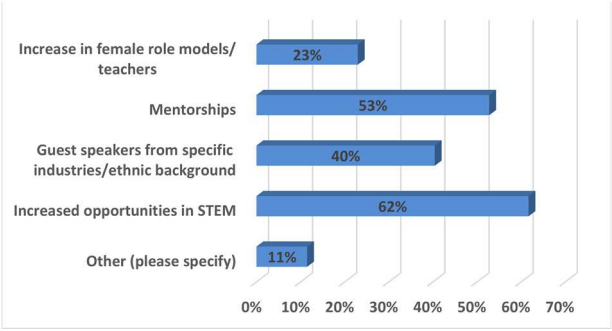


Fig. 10. Type of support required during the STEM degree

As shown in Fig. 10, mentorships are a commonly mentioned form of support that many participants feel they need in their STEM programs. This indicates a desire for guidance and one-on-one support. There is a strong desire for increased opportunities in STEM, which suggests that students want more practical experiences, internships, and career opportunities during their degree programs. The need for more female role models/teachers and guest speakers from specific industries/ethnic backgrounds highlights the importance of diversity and representation in STEM education.

## F. *Experiences Studying a STEM degree*

The questionnaire invited the participants to share additional comments about their experiences pursuing a STEM degree. Out of the 235 participants, 169 provided responses to this open-ended question. Rather than employing automatic sentiment classification, we conducted a manual analysis for a more accurate understanding of the diverse responses. Sentiment analysis conventionally categorizes text as positive, negative, or neutral based on its emotional tone. However, upon reviewing the responses, we observed that some did not distinctly fall into positive or negative categories; rather, they conveyed mixed emotions or addressed complex situations. Therefore, we chose to classify the responses into four categories based on the degree of underlying sentiment:

- Negative: for comments expressing dissatisfaction, unhappiness, or complaints.
- Neutral: applied to comments that are inquiries, information-sharing, etc. irrespective of sentiment.
- Positive: assigned to comments expressing satisfaction, happiness, or similar sentiments.
- Mixed: designated for responses conveying a combination of positive and negative feelings.

Upon analysis, the overall sentiment regarding STEM experiences is predominantly positive, with 45% of responses reflecting positive opinions. In contrast, only 11% of responses are negative, 33% are neutral, and 11% present mixed feelings as illustrated in Fig. 11. The participants' experiences studying STEM degrees manifest a broad spectrum, encompassing both positive and challenging aspects. Some convey great enjoyment and fulfillment, while others highlight difficulties and concerns.

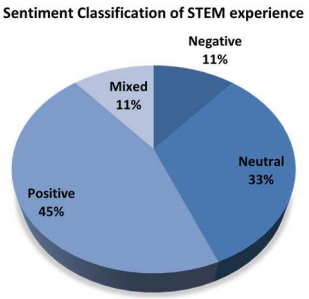


Fig.11. Evaluating the Sentiments in STEM Experience Survey Data

Negative responses encompass various concerns, including mental health challenges, uncertainties regarding career prospects, a sense of inadequate support from peers and lecturers, and instances of sexism and perceived unfair representation within the university. For instance, one participant highlighted, '*Even with the majority of students being females, the majority of my lecturers are male which sometimes shines a light on disproportionate representation in professional roles in this sector.'*

The neutral responses, while not strongly positive or negative, offer insights into challenges and difficulties. For instance, participants note a perception within certain STEM fields, such as psychology, that they are not always regarded as "hard" sciences. This perception, as expressed by one participant, raises concerns about its potential impact on confidence and the perceived value of their degrees compared to more traditional STEM fields like engineering or chemistry: *'I think psychology is now female-dominated, and this, alongside its growth on social media, has made it seem like a cheap or useless subject. I often hear about people dismissing psychology as a pseudo-science that people study because it is easy according to them.'*

Participants commonly convey positive sentiments regarding their STEM degree experiences, emphasizing enjoyment, fulfillment, and the acquisition of valuable skills. Numerous participants describe their experience as *'brilliant'* and *'rewarding'*, expressing gratitude for the support, opportunities, and overall enriching nature of STEM degrees. Despite the positive experiences, some participants recognize the potential loneliness associated with studying in a gender-imbalanced environment. For instance: *'I love it and wish I could have more female friends who would understand what I'm talking about. Outside university, I mostly communicate about the subjects of my study with my male friends.'*

Participants appreciate the diversity present in their courses, yet they also recognize the need for enhancing inclusive learning environments, resulting in a spectrum of sentiments. Consequently, some participants express mixed feedback, acknowledging both positive and negative facets of their experiences. For instance, while enjoying their STEM degree, they encounter challenges or conflicts. A representative mixed response reads: *'Studying a STEM degree was absolutely a delight. There are perks in being part of a team that shows a lot of compassion with sharing experiences and ensuring that students make the best of themselves. However, the downside is that some lecturers have biases towards students, especially female lecturers who strive for women in STEM, neglecting male students at times. I stand for equality in any field, and if you have the skills, you are a good fit no matter what the gender.'*

It is important to note that sentiment analysis may not capture the full context and nuance of these responses, as some challenges are deeply personal and multifaceted. Additionally, some responses are more informative than emotional, making it challenging to categorize them in terms of sentiment.

### G. Discussions

The findings from the current study align with and expand upon existing literature regarding the challenges and opportunities for female students in STEM education. The synthesis of our results with the broader body of research provides a comprehensive understanding of the multifaceted issues surrounding female representation in STEM and informs potential interventions and policy changes.

Our study supports the consistent theme in the literature that female students face internal difficulties during their STEM education. These challenges, ranging from self-doubt to balancing work and personal life, mirror the findings of previous research [10][11]. The identification of such internal challenges emphasizes the need for targeted support mechanisms, including mentorship programs and initiatives that address the emotional and psychological well-being of female students. The identification of work placements/experience and university open days as significant motivators for female students aligns with the literature's emphasis on the importance of practical exposure and positive role models [8][15]. This consistency emphasizes the potential impact of early engagement and exposure to STEM environments in encouraging more women to pursue STEM degrees. Also, our study extends the understanding of challenges faced by different ethnic backgrounds, with Asian/Asian British students reporting higher levels of internal difficulties. This nuanced insight supports the notion that challenges are not universal and may vary based on cultural and ethnic contexts [23]. Tailoring support mechanisms to address specific challenges faced by different ethnic groups is crucial for creating an inclusive STEM environment.

The experiences of sexism reported by a substantial portion of our participants provide support for the existing literature highlighting gender-related issues within STEM education and the workforce [24][12].This underscores the persistent nature of gender biases and discrimination, emphasizing the need for proactive measures to create safe and equitable environments for female students. The preferences expressed by our participants for more opportunities in STEM and mentorship programs are consistent with the literature emphasizing the positive impact of mentoring and targeted support on female students' self-belief and motivation [15]. Incorporating these preferences into institutional policies can contribute to a more supportive and encouraging STEM learning environment.

The findings from our study have significant implications for policy and practice. Institutions should consider implementing targeted mentorship programs, fostering practical experiences, and addressing internal difficulties through counselling and support services. Initiatives to combat sexism, such as involving men in gender equality efforts, should be explored to create a more inclusive culture within STEM disciplines [12]. While our study provides valuable insights, it is essential to acknowledge its limitations. The study focused on a specific cohort of female students at Middlesex University, and the findings may not be fully generalizable. Future research could explore these issues across diverse institutions and STEM disciplines to capture a more comprehensive understanding. Additionally, qualitative approaches may be employed to delve deeper into the nuanced experiences of female students in STEM.

## V. Proposed Support System for Women in STEM

### A. Set of Recommendations

Molnar et al. [24] acknowledge that the emphasis in diversity initiatives should be on reforming the system rather than attempting to change women to fit within existing structures. Addressing underlying issues, such as the undervaluation of women's voices, is crucial. Trying to conform women to the current system may hinder diversity, as its essence lies in embracing a variety of approaches and opinions. Thus, the approach would be to propose a support system that aims at changing the culture in STEM. Consequently, this section aims to compile a set of recommendations from the current study.

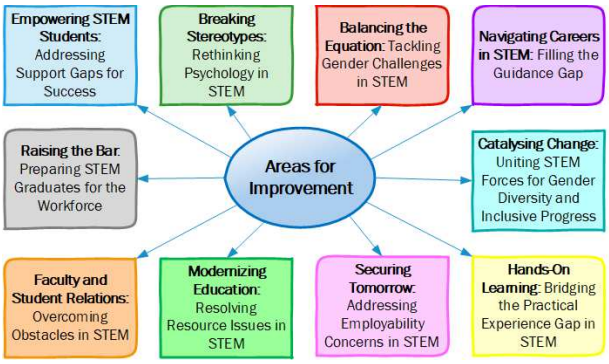


Fig. 12. Areas for improvement.

Fig. 12 illustrates ten improvement areas identified from the questionnaire that are broken down below:

- **Empowering STEM students:** more support should be provided to help the female students succeed in their STEM studies.
- **Breaking Stereotypes:** implement a combination of strategies including structural and cultural initiatives to foster a more inclusive environment and provide meaningful support to students facing challenges related to the perceived status of their discipline within STEM.
- **Balancing the Equation:** tackling the gender challenges by increasing the female role models in certain STEM fields, addressing gender imbalances in leadership roles during group work, and the gender pay gaps in the industry.
- **Navigating Careers in STEM:** enhance career guidance services, broaden female students' exposure to STEM careers, and better prepare them for the diverse opportunities available in the field.
- **Catalysing Change:** by fostering partnerships with professional and network organization, initiatives can leverage the expertise and resources of these organizations to promote inclusivity, encourage mentorship programs, and implement strategies that support the advancement of women in STEM.
- **Hands-On Learning:** create a more immersive and practical learning environment, ensuring that STEM female students acquire the hands-on experience necessary for success in their future careers.
- **Securing Tomorrow:** better prepare STEM female students for future employment, alleviate concerns about employability, and foster a seamless transition from academia to the professional workforce.
- **Faculty and Student Relations:** work towards creating an inclusive and supportive environment where female students feel valued, respected, and empowered to seek help when needed.
- **Modernizing Education:** create a more dynamic and responsive learning environment that meets the evolving needs of students and maintains the quality and relevance of educational resources.
- **Raising the Bar:** contribute to a more robust and industry-aligned educational experience, addressing concerns about female students' preparedness for the workforce and enhancing their competitiveness in the job market.

### *B. Proposed Support System*

To foster empowerment among women in STEM, it is imperative to implement targeted interventions and enhancements that enrich their overall educational experience. The recommendations derived from this study, along with key findings from existing literature, serve as the foundation for the proposed support system aimed at paving the path for empowering women in STEM. Consequently, the proposed robust support system depicted in Fig. 13, aligns with a broader vision aimed at catalysing transformative changes in STEM education. At its core, the primary objective is to create inclusive opportunities for all women to actively participate in STEM-related pursuits. To achieve this, we have identified three stages, such as:

- **Stage 1: Outreach:** through family workshops led by current women STEM students and professionals, aiming to dismantle stereotypes and encourage young girls to participate in sustainable innovation and technology projects [8]. An additional goal should be to raise awareness of feminism, advocating for men to become allies in broadening women's career choices [12].
- **Stage 2: University Journey:** the study presented in this paper, identified the need for support and mentorship for women once they enter STEM subjects at the university level. Consequently, a tailored support system is proposed, consisting of: (1) *Pastoral Support and Mentoring Scheme:* introducing a buddy system and mentorship programme involving students, staff, and alumni; (2) *Identifying Role Models*: assisting students in connecting with female role models in STEM; (3) *Development Programme:* initiative to enhance self-reliance, social connection, self-worth, and confidence among female STEM students through a series of workshops; (4) *Workshop for All:* integrating workshops addressing sexism and antisocial behaviour into the curriculum, fostering inclusive and tolerant communities; (5) *Pioneering progress in STEM:* collaborate with professional and networks organizations in STEM to champion gender diversity, foster collaboration, and empower women—creating a transformative environment and contribute to lasting solutions that enhance opportunities for female individuals in STEM professions.
- **Stage 3: Professional Journey:** the final stage focuses on female STEM students transitioning from university to the industry. Workshops and mentorship programs, including collaboration with industry events, could facilitate this transition [20]. The aim is to foster collaboration between universities and industries to enhance women's successful entry into professional spheres.

## VI. Conclusions and Future Work

This paper presents a study into the challenges encountered by female students during their STEM education, shedding light on potential obstacles that hinder the progress of women in STEM. The study involved 235 female student participants and data was collected through a questionnaire. The analysis identified mechanisms to improve the presence of women in STEM subjects and support their career progression. Additionally, the study provides a compilation of recommendations that encompass fostering progression, retention, and continuous development of professional careers. Finally, a robust support system is proposed to pave the path for a supportive environment, ensuring sustained success and empowerment for women in STEM. As future work we plan to extend the study with interviews. We also plan to run a questionnaire targeted at women professionals in

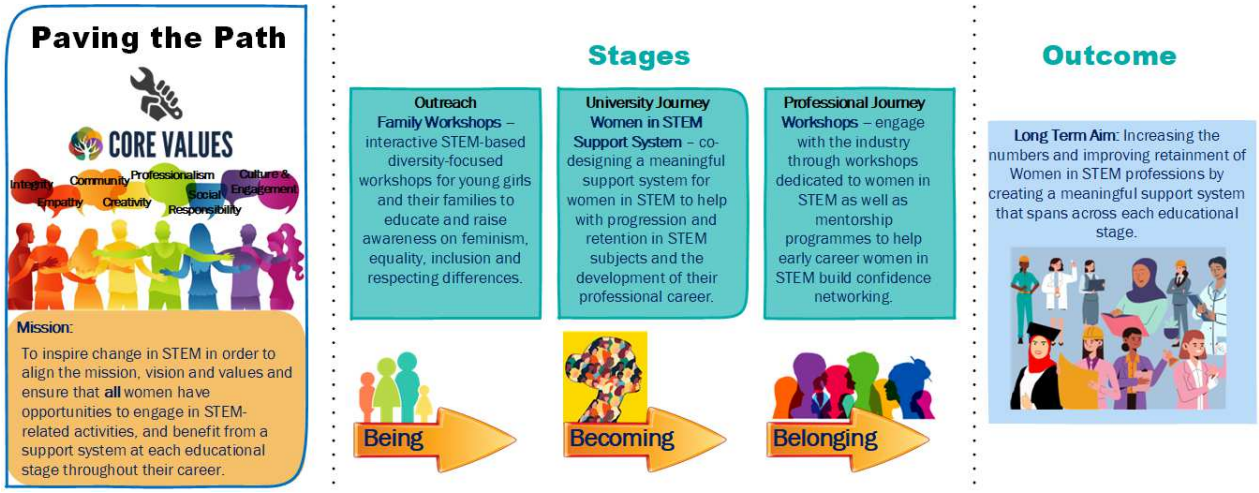


Fig. 13. Paving the Path

STEM. The study will try to understand the type of support the industry offers to their female employees to bridge the gap and offer a smooth transition into industry.

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