Capstone Project

Promoting Gender Diversity in STEM Education

GPFF407-01: Diversity in the College Class

Submitted by:

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***Strategies and interventions to address gender disparities in STEM education including mentorship programs, curriculum reforms, outreach efforts, and initiatives to combat gender bias and stereotypes.***

**Introduction**

STEM is an acronym for science, technology, engineering, and mathematics. In the 1990s, the National Science Foundation identified that the shortage of students in STEM fields would result in a poorly prepared workforce in the face of industrial and economic development challenges at a time of global competitiveness (Sanders, 2009). STEM fields play a pivotal role in enhancing an economy's innovative and technological capacity. However, women are underrepresented in these fields. It is argued that STEM is the fundamental discipline that can help to achieve Sustainable Development Goals (SDGs); however, evidence suggests that the percentage of females getting enrolled in these subjects is lower than that of males, particularly in Engineering related disciplines. United Nations Women section suggests that an increase of women in STEM education and STEM professions is critical to find out improved solutions for global challenges as it would increase the potential for innovations (Benavent et al., 2020).

Today's world relies on information and technology. With increased economic importance and the specialization of technological knowledge and expertise, more jobs are required in STEM fields. As a result, the demand for a STEM workforce will likely rise further in the coming years (OECD, 2008). In response to these demands, secondary education is familiarizing students with STEM fields (Ormond & Zandvliet, 2016) through outreach efforts to increase students' motivation towards STEM courses and make them pursue careers in them to meet the demands of today's job market. To avoid a possible shortfall of engineers and scientists, countries such as the US need to support their local talent by improving enrolment and retention of those under-represented in STEM fields, including women and minorities (Tsui, 2007). To address gender and racial disparities in STEM participation, various interventions have been designed to operate in colleges and universities. These programs include various activities and services that influence students' skills, motivation, and interests in STEM (Bayanova et al., 2023). It is suggested that schools, family, government, business, and industry should primarily be held responsible for increasing the participation of under-represented groups in STEM as only working together synergistically can help to achieve more collectively than as separate bodies.

Currently, the lack of gender diversity is one of the significant issues that academia and technological organizations face (Charlesworth & Banaji, 2019). Also, research shows that the number of females registered in STEM subjects has been declining in the past two decades, and the number of females resigning from technological jobs is increasing (Botella et al., 2019). It is suggested that continuous efforts to increase enrolment and retention of female students in STEM fields can help to reduce the challenges that women face in STEM disciplines.

The information and communication technology (ICT) sector has grown drastically in the past two decades. This sector has shown remarkable potential for innovation and has introduced changes with a profound impact on society. The ICT sector requires a large number of employees with graduation in STEM subjects in order to take advantage of knowledge, brain power, and creativity. However, it has been unable to do so as several studies reveal that the ICT sector is male dominated, with females working only part-time, taking breaks from this profession or even quitting their jobs (Lamolla & Ramos, 2018). The low percentage of females in high positions and gender pay gaps are realities of the ICT sector (Ashcraft et al., 2016). It should not be ignored that gender diversity has been proven to enhance the potential for innovations (Botella et al., 2019); hence, gender diversity needs to be promoted in this sector.

Research has identified factors responsible for the persistent under-representation of females in STEM subjects. For instance, early sex differences in interests towards STEM fields in a way that boys express more positive attitudes toward STEM subjects, which may lead to gender disparity. Such attitudes may also result from social stereotypes communicating that STEM fields are more appropriate for males than females. In addition, female participation in STEM may also be undermined due to the lack of female role models (Moss-Racusin, 2016).

A large number of scholars believe that there are gender disparities across STEM disciplines, and gender bias is one of the factors that influence female students' decisions about participation in STEM education at high school (Jeffries, Curtis & Conner, 2020). Gender bias has a substantial impact on female STEM students' perceptions; it consciously and unconsciously creates a gender gap that continues to affect the educational life of the students (Kirkland, 2023). Gender roles and gender stereotypes as to what professions are appropriate for males and females are deeply embedded in society and family. They greatly influence both men's and women's academic and career choices (Weisgram et al., 2010).

Intervention strategies aimed at combating gender disparities and diversifying STEM talent pool include Summer-Bridge Programs, Mentorship Programs, Tutoring, Research Programs, Career Counseling, Learning Centers, Academic Advising, Workshop and Seminars, Financial Support, Curriculum and Instructional Reforms, and outreach activities (Tsui, 2007). However, this paper discusses Mentoring Programs, Curriculum Reforms and Outreach Efforts.

**Goal of the Project**

The project aims to explore strategies and interventions developed to address gender disparities and promote gender diversity in STEM fields.

**Literature Review:**

For decades, interventions have been created and in place to ensure inclusion, diversity, and retention in STEM fields. This section explores the existing interventions that include mentorship programs, curriculum reforms, and outreach activities to promote diversity and address gender bias and stereotypes.

***Mentorship Programs***

Mentoring refers to a process where an experienced mentor leads, guides, teaches and counsels inexperienced or less experienced individuals called mentees, students, or protégés (Crisp & Cruz, 2009). Here, mentoring is defined as a developmental relationship aimed at supporting a learner's growth involving several mentors with different skill sets and assets. Research shows that if implemented effectively, mentoring helps students overcome barriers impeding their success (Pfund et al., 2016). Measured by enrollment in graduate school, completion of a degree, or achievements related to a career, mentoring remains a predictor of success in the STEM field (Woodcock et al., 2016). According to Packard (2015), mentoring is a promising strategy for recruiting and retaining individuals from under-represented sections of society.

Mondisa, Packard & Montgomery (2021) argue that gender and racial disparities persist in STEM education despite decades of mentoring interventions aimed at improving enrollment and retention. They introduced a framework called STEM Mentoring Ecosystems (STEM-ME) to evaluate and critique existing mentoring ecosystems and provide suggestions for improvement. To better understand the overall scenario, they mapped out the structure of the STEM mentoring ecosystem related to minoritized and historically excluded individuals in STEM.



**Figure 1: STEM Mentoring Ecosystems**

In higher education, mentoring occurs between faculty-student, faculty-faculty, and student-student by program administration and in program cohorts. Figure 1 identifies stakeholders and systems that collaborate and make concerted efforts in STEM mentoring ecosystems. Those stakeholders include mentors, mentees, and stewards working in academic and community/home micro-systems. The stewards are responsible for negotiating resources such as funding and training and for assessing and cultivating synergies within micro-systems. In this way, the STEM-ME framework helps evaluate existing mentoring infrastructure, resources, prospects for developing new structures, identification of stewards and required investments. In other words, it identifies assets and gaps in prevailing STEM mentoring ecosystems.

Much mentoring occurs through formalized programs that overlook those who are not involved. Milkman, Modeupe, & Chugh (2015) found that faculty, regardless of gender and race, were more willing to respond to mentoring requests from white male students. It shows that the culture has not changed despite the availability of more mentoring programs (Beck et al., 2022). Also, due to expense in terms of time and cost, this program-based mentoring serves a small number of students and excludes those who might be interested in participating otherwise (Packard, 2015). Hence, outside of programs, informal mentoring should include a broader range of mentors and students. In this case, a student may need a mentor from a similar demographic background, and unavailability highlights the isolation of minority groups in STEM fields (Crisp et al., 2017).

According to the National Academies of Sciences, Engineering, & Medicine (2019), it is critical to understand mentoring, access, and equity from minoritized groups’ point of view. Research should assess the impact of mentoring ecosystems on mentoring experiences, problems related to inequalities, and access to mentoring of minority groups in STEM fields. This requires disruption, which allows new approaches to be part of the system. Recognizing the mentoring requirements of minority populations and placing them at the centre can help advance mentoring ecosystems that support the enrollment and success of students (Marshall et al., 2022).

The existing STEM mentoring ecosystems are not functioning in a way that produces the kind of mentoring STEM fields actually require. In order to ensure beneficial, sustained, and consistent mentoring, they suggest that investment should be made to cultivate STEM mentoring ecosystems intentionally (Mondisa et al., 2021). It is critical to transform the STEM academic system that has been resistant to change, particularly in advancing equity and diversity.

STEM instructors are an essential target group in case of evidence-based interventions aimed at reducing gender bias since they are responsible for training, evaluating and mentoring the next generation of scientists. In other words, they can either halt or perpetuate the transfer of gender biases to the next generation (Moss-Racusin, 2016). Further, Pfund et al. (2015) even argue that STEM instructors’ willingness to mentor female students can directly impact their persistence in academia. However, empirical evidence points out that STEM instructors have subtle gender biases similar to those observed in the general public (Kong et al., 2020). Life sciences educators, i.e. biologists, demonstrate as much gender bias as educators in other STEM disciplines, i.e. mathematics and physics (Milkman et al., 2015). Hence, the implementation of tested and validated gender bias interventions is critical in order to improve the participation of talented females in STEM fields (Moss-Racusin, 2016).

***Curriculum Reforms***

Curriculum is an important policy area that can promote gender equality. It directs teaching and learning through different stages of education, from pre-primary to tertiary and non-formal education. It demonstrates what a student would learn and achieve, including knowledge and skills. Hence, it helps society to realize economic and social development. The learning process involves teachers, students, learning methods, expected and unexpected outcomes, and outputs. According to UNESCO (2020), The Beijing Declaration and Platform for Action emphasized the development of gender-sensitive curriculum, teaching materials, and textbooks; however, school textbooks and culture did not adequately reflect gender equality.

Losioki & Mdee (2023) argue that the hidden curriculum continues to impact educational practices, resulting in imbalanced gender depiction in textbooks and gender inequality. Textbooks, being the source of information and guide in the teaching and learning process, add to the development of particular perceptions, social norms, and behaviors for students from both genders. Although the representation and visibility of females have improved, the gender roles given to them in textbooks foster stereotypical ideas and gender bias (Casad et al., 2021). Losioki & Mdee (2023) suggest that Governments should collaborate with relevant authorities to ensure that curriculum development considers gender balance in role allocation and gender-responsive content. Also, awareness should be created among book authors and reviewers regarding gender sensitivity in preparing a curriculum that adheres to the principles of gender equality (Kim, Chu & Lim, 2015).

Diverse strategies have been adopted to reduce gender disparities in historically male-dominated STEM fields, such as early exposure to vocational and academic STEM courses, to boost interest in and preparedness for these subjects. Sevilla, Luengo-Aravena & Farias (2023) used the case of Chile's remarkably differentiated school system in order to examine secondary curricula's impact on students' enrolment and retention in STEM subjects taught at universities and vocational post-secondary institutions. They wanted to find out if early exposure to STEM courses results in reduced gender disparities in STEM higher education. Findings showed that early exposure to STEM courses increases students' chances of getting enrolled in STEM programs at the university level, but it does not impact later persistence.

On the contrary, exposure to applied STEM courses in the vocational tracks has a better impact on both enrolment in STEM programs in post-secondary vocational institutes as well as persistence. However, gender gaps are amplified in this STEM pipeline as male students benefit more than female students from early exposure to applied STEM courses. It was also seen that enrolment in STEM university programs from vocational track with applied STEM courses increases women's participation in STEM programs, leading to reduced gender disparities.

Sevilla, Luengo-Aravena & Farias (2023) concluded that although secondary STEM courses lead to increased female participation in STEM higher education, that alone is not sufficient to attain gender equality in STEM as gender disparities expand in more effective ways. In the case of greatly differentiated school systems, school authorities and policymakers should extend increased support to female students willing to study and develop careers in STEM to improve their participation in these fields. Also, high school students should be allowed to choose academic and applied STEM courses as part of their non-mandatory curriculum.

***Outreach Activities***

In recent times, in addition to regular curriculum, colleges and universities have introduced activities aimed at facilitating the transition between secondary education and higher education, such as student-mentor programs and summer science programs. Recently, higher education institutions or STEM-based companies, in collaboration with secondary schools, have developed outreach activities – both in and out of school - that are aimed at creating awareness among students about STEM subjects and motivating them to pursue careers in STEM fields by linking science, they study at school and the way it is applied at work (Bussard, 2021). These activities are defined as processes that bring information or services to individuals, such as teachers and students, beyond regular constraints. These activities, developed in collaboration with universities or industry, provide information usually unavailable to students and teachers and are regarded as outreach activities (Vennix, den Brok & Taconis, 2017).

Outreach activities are diverse in nature and include hands-on activities in workshops; sharing of expert knowledge and new perspectives and application of STEM in guest lessons; visits to workplaces and carrying out of activities in that work environment; initiation and supervision of actual company-based issues carried out at the company or schools (Vennix et al., 2017). The important features of outreach activities are the real-life context and the active role of STEM-based organization employees.

Using data from the US and the Netherlands, Vennix, den Brok & Taconis (2018) empirically examined outreach activities by investigating high-school students’ perceptions of the outreach learning environment, self-reported attitudes and motivation for STEM fields, and perceived need fulfilment. It was found that outreach learning environments positively impacted increasing students’ motivation towards STEM fields and that the impact varies according to the specific features of the activities. It is argued that several outreach activities are being offered, but their impact has not been examined.

**Girls4STEM Initiative**

Benavent et al. (2020) discuss the Girls4STEM program, which was started in 2019 by the University of Valencia, Spain, with the objective of breaking stereotypes associated with STEM professions and having more students, particularly girls, opting for STEM disciplines. In other words, the project aims to reverse the female underrepresentation in STEM disciplines. The major goals of the project included the promotion of STEM vocations; arousing curiosity among children aged 6-18; encouraging participation of multiple actors such as students, family, teachers, educational institutions, STEM-based companies, and female STEM experts; creating awareness as to STEM advances and their social value; and increasing the visibility of female STEM professionals and their contributions to STEM fields. The project operates through outreach activities and involves three main actions: Girls4STEM Family Talks, Professional Talks, and Training Seminars.

The cornerstone of this project is the Girls4STEM Professional Talks, where pre-university students interact with female STEM experts and learn about STEM disciplines and the daily routine of a STEM professional. This informal learning environment proves to be seminal in the development of interest in STEM subjects. This strategy promotes STEM self-efficacy and perception of STEM subjects to achieve communal goals and provides professional orientation opportunities. STEM4Girls Family Talks are based on videos of the professional lives of STEM experts, which acquaint them with the professional and personal benefits of being a STEM woman. Initial Training Seminars are aimed at explaining the project's objectives to pre-university teachers who will be part of it.

The analysis shows that breaking gender stereotypes linked to STEM disciplines should start by explaining the range of disciplines under the STEM domain (Kerkhoven et al., 2016). Also, results show that girls lack confidence in their STEM performance. This requires the elimination of prejudice and improvement in the self-confidence of females in STEM subjects, as evidence points out that self-confidence in STEM is the determinant of persistence in these fields over time. Evaluation of the project shows greater involvement of primary schools, as evidence indicates that the gender STEM gap is initiated at the age of six.

**ETSE-UV Working Program**

Botella et al. (2019) documents a gender equality plan adopted by ETSE-UV of the University of Valencia (UVEG), Spain. The ETSE-UV working program supports four key actions to decrease gender diversity gap illustrated in Figure 2.



**Figure 2: Key actions to reduce Gender Diversity Gap** (Botella et al., 2019).

Those four actions of the working program include: First, the provision of institutional support and encouragement; second, to expand professional support; third, to promote leadership; fourth, to ensure visibility of women role models. The ETSE-UV constitutes the university's engineering programs, which include Telematics Engineering, Chemical Engineering, Multimedia Engineering, Industrial Engineering, and Computer Science Engineering. Due to the broad range of offered degrees, the ETSE-UV experiences challenges while attempting to reduce gender disparities in STEM at all levels, including student, academic, and professional levels.

Being a higher education institute, the ETSE-UV can help to reduce gender disparities in STEM first by collaborating with secondary schools to deal with stereotypes, second, by engaging and retaining female students after they get enrolled and providing them with professional support networks during their career; third, by increasing the presence of females in higher academic positions or leadership roles in order to create more gender-balanced environment; and fourth, by improving the visibility of women role models which will underscore the applicability of various STEM fields. The ETSE-UV program aligns with the interventions suggested by UNESCO, such as mentorship, role models, and student engagement through extra-curricular activities. The actions proposed by the program are also supported by the evidence and conclusions from existing literature (Smith & Gayles, 2018; Weisgram & Bigler, 2006).

**Discussion**

Research has identified a lack of diversity as a key challenge in computing and engineering fields (Pournaghshband & Medel, 2020). As a result, educators and researchers in this field have been making efforts to encourage diversity and inclusive practices. For this purpose, several techniques, including peer mentoring, service learning, project-based learning, robotics, and public goal-oriented programs, were implemented to achieve diversity (Bego & Nwokeji, 2021). Despite these efforts, a lack of diversity persists in engineering and computing professions.

The diverse population in the engineering and computing field has multiple benefits, such as diversity leading to innovation (Hofstra et al., 2020), which is essential for improving economic competitiveness, the standard of life, and national security. Teams constituting diverse populations have unique skill sets, interests, and abilities, which help identify real-world problems and solutions. Also, the diverse student population has educational benefits such as social development and practical competence. Though diversity and inclusion are crucial in education, recent research shows that engineering and computing lag behind other fields in recruiting and graduating under-represented minorities (Bego & Nwokeji, 2021).

Through a review of diversity research in engineering and computing education, Bego & Nwokeji (2021) found that minority students experienced biases and discrimination, resulting in lower perceptions of belonging and inclusivity, which led them to change majors or leave college altogether. However, minority students’ perceptions and results following active learning interventions are found to be positive in some cases and negative in others.

It is observed that most of the existing diversity interventions and strategies have not been subject to systematic evaluation; hence, their efficacy has yet to be known (Paluck & Green, 2009). Only a few diversity interventions are validated, but evidence suggests that none of them targets the gender biases of STEM instructors (Moss-Racusin et al., 2014). Evidence indicates that some interventions can backfire, exacerbate biases, and undermine diversification efforts (Dobbin et al., 2015).

**Recommendations**

More quantitative and intervention-based research must be done as existing diversity research identifies issues while offering no solutions (Bego & Nwokeji, 2021). In order to confirm the impact of the ETSE-UV working program, a target group of female students should be tracked during their academic years, and regular interviews and surveys should be conducted each year. Future research needs to systematically evaluate gender diversity interventions to determine their efficacy in reducing gender bias and promoting gender diversity in STEM education.

**Conclusion**

The gender diversity gap in STEM fields is the result of multiple factors. Each factor has a different impact and requires collective action by a number of institutions and actors to create a gender-sensitive culture. It was found that there are relatively few diversity interventions with the objective of decreasing gender bias within the STEM community. Hence, interventions and strategies that target the STEM instructors' biases are also needed since gender bias distorts students' meritocratic evaluation and progress.

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