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Empowering Gender Equity in STEM Education: Skills for Today and Tomorrow

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Abstract

Education is a cornerstone of human development, yet many girls and women still face barriers to access. Scholars in human resource development stress that inclusive education is essential for social, political, and economic progress. This article argues that equitable access is not only vital for development but also a constitutional right. Despite progress, true gender equity in education remains out of reach. Using a social justice lens, the article calls for inclusive learning environments that overcome gender and cultural barriers. It draws on the Capabilities Approach, which emphasizes enabling individuals to pursue meaningful lives, and Social Cognitive Career Theory, which explores how socio-economic and cognitive factors shape educational outcomes. Persistent challenges—such as sexism, patriarchy, poverty, and gender-based violence—continue to limit opportunities for women. The article uses secondary data to highlight these issues and offers strategies for policymakers and institutions to create more equitable and transformative higher education systems.

Keywords: gender inequality, access, equitable, higher education, science education

1. Conceptualizing the Gaping Gaps in Science Education

Broadly, science education encapsulates learning areas/fields such as Science, Technology, Engineering and Mathematics- STEM. Smith and Monday (2019) argue that the gender skew in STEM education denies the world the potential to explore and benefit from a myriad of skills that women scientists can offer in various science fields. Globally, a case has been made for women and girls' under representation in science education, and profession. This is documented in United Nation Development Programme [UNDP] report of (2024) and, the United Nations International Children's Emergency Fund [UNICEF], (2023). American government Report on "STEM" alludes to the fact that science education is categorised as follows- [the physical, biological, and agricultural sciences]; [computer and information sciences]; [engineering and engineering technologies]; and [mathematics]. This clustering is entrenched in most education systems across the globe. In general, STEM fields are widely regarded as critical to developing national and global economies (National Academy of Sciences, Committee on Science, Engineering & Public Policy, 2007; Ministry of Education -National Plan, 2001). The Academy of Science of South Africa- Assaf recognises and aligns with this view. ASSAf was formed in response to the need for an academy of science congruent with the dawn of democracy in South Africa. Emblematic of the underrepresentation of certain groups of people in accessing and succeeding in STEM fields in South Africa- [girls and women included], ASSAf is geared towards addressing common ground of scientific knowledge and activity. ASSAf endeavours to remove barriers between people and obstacles to full development of their intellectual capacity.

Calls to strengthen and seal the leaking gender pipeline in order for women and men to be competent and favourably in global economies are gaining momentum internationally. This impetus is based on the high value that is associated with the field. We therefore align with interventions that strive for equitable access, representation and participation in science education. Due to their overall positioning in society, STEM careers are often referred to as the jobs of the future, driving innovation, social well-being, inclusive growth and sustainable development (Hill et al., 2010; UNESCO, 2021). Assumably, people in this work force are responsible for improving living standards through innovative inventions, spurring economic growth, and propelling global competitiveness. They catapult a nation's innovative capacity through their work in research and development (R&D), and in other technologically advanced activities (AAUW, 2008; America-Science and Engineering Indicators, 2022). It is further illustrated that, by including workers of all educational backgrounds and the wide variety of occupations that require significant STEM knowledge and expertise, the STEM workforce represented 23% of the total U.S. workforce in 2019. Employees in STEM fields had a higher median pay ($55,000) than non-STEM workers ($33,000). Notably, the same data showed that women are about 34% of STEM workers, representing 44% of those with a bachelor's degree or higher and 26% of those without a bachelor's degree. Wei therefore argues that it is important to include women and girls in science education on the basis of the attributes and value it embodies- none should be left behind.

In the interim, making education relevant for the 21st Century continues to occupy key national and international discourses. Educating for the 21st Century skills requires leveraging opportunities in education sector to prepare all learners and students for the workplace. Skills and capabilities for the 21st Century include deep learning, machine learning, robotics, workplace change and preparedness, expert thinking and complex communication (Luterbach & Brown, 2011). Subsequently, calls to embed creativity in technology and innovation across the curriculum are currently dominating education discourses are growing louder. Henriksen et.al (2016) argue that closing the gender gap requires these skills to be made accessible to everyone- for they are not a preserve for a few talented learners/students. Arguably, Science, Technology, Engineering and Mathematics as a male dominated field remains a priority focus area globally for higher education institutions. Although women comprise half of the global population, they are however underrepresented in the STEM fields (Ladachart & Ladachart, 2025). Ladachart's study — done in Thailand alludes to the fact that gender inequality in STEM is perpetuated through masculine dominance, lack of female agency and feminine ways of engagement.

It is notable that heightened advocacies around gender inequalities and underrepresentation in education have improved enrolments for girls and women in various tiers of education globally. However, current statistics indicate that although there are many girls in education than before, they do not get the opportunity to benefit equally from education of their choices according to UNESCO (2022). As a result, UNESCO is giving this area special attention through research, policy and capacity building. These mechanisms are aimed at empowering girls and women through education. Furthermore, the American Association of University Women Education -AAUW (2008) and Hoffman (2021) argue that, despite the progress made towards girls and women's education, there are very few women scientists and engineers. The authors worry about the gaping gender gap in STEM *there are so few women becoming scientists and engineers.* Understandably so, the worry can be linked to Simth & Monday (2019) who noted the travesty of the world missing on talents and skills that women scientists have to offer. Inconsistencies in STEM access have also been noted with countries with high gender equality levels. Conjectures from Finland, Norway and Sweden indicate that the countries lead in gender equality but, paradoxically, the STEM gap is very pronounced in these countries — which is commonly referred to as [*educational-gender-equality paradox*] (Stoet & Geary, 2018).

Trends in International Mathematics and Science Study data- [focusing on high- and middle-income countries] of 2019 of grade 8 learners concluded that more boys than girls would want to pursue a career in Mathematics or in a Science related field. When factors *like confidence and achievements* were considered, it was concluded that, a learner/student with high confidence in Mathematics and Science related fields was highly likely to enter a job in the same fields. The study further revealed that at grade 8, boys were more confident in Maths than girls. The gender differences were less pronounced in Science (Hencke et al., 2022; Wang et al., 2020). The conclusions of the TIMMS study align with Ladachart and Ladachart (2025) and Mqadi (2025) in arguing for the appropriation of the role of sociocultural ideologies in STEM teaching and learning Consistent with TIMMS findings, Bodnar et al. (2020) argues that the science identity is an antecedent to a career in STEM across gender and race- especially for boys and males. According to Mqadi (2024) and Wang et al. (2020) social cultural factor- parents and teacher; gender prejudiced curriculum material, inadequate employment for female teachers [who are roles models in STEM] contribute to low enrolment in STEM studies. Furthermore, while research has also shown the gender disparity in STEM courses; young women who are high achievers in Mathematics and Sciences to study biology, medicine or psychology majors instead of pursuing physics, mathematics and engineering courses (Bieri Buschor et al., 2014; Sax et al., 2018). This is notwithstanding Sax et al. (2018) conclusion that biological sciences is the only field that has attained gender equality in the STEM field. UNESCO (2022) maintains that the due to the gender skew in STEM, the world ends up [*Missing out on half of the world's potential*] (Smith & Monday, 2019). This has been attributed to the fact that they assess their abilities on a lower scale than boys with the same achievement levels. It is also likely that they hold themselves to higher standards, believing that they have to be exceptional in order to succeed in these areas.

Another point of tension that exacerbates gender skewing in STEM is based on career aspirations and confidence (TIMMS, 2019; Sax et al., 2018). Data has revealed that low performing boys are more confident to pursue careers in Mathematics in comparison to low performing girls. The low aspiration of girls at this level could lead to fewer girls entering the STEM field at tertiary education level (Bieri Buschor et al., 2014; Sterling et al., 2020). It also emerged that although 99% of the female learners had enrolled for mathematics and physical science, only 32 % intended to continue with engineering studies at tertiary level (Bieri Buschor et al., 2014). Moreover, other studies have shown that parents or role models play an important role in the uptake of STEM.

Associated intersectional factors such as race, gender and self-rated math ability, which keep shifting are key indicators in determining enrolments in STEM fields. Low confidence levels towards STEM education by girls and women has been largely linked to parental and societal attitudes toward a female child being *"able" and apt* to study engineering or related courses. An excerpt from a study by Mateescu and Ionescu (2019) in schools in Johannesburg noted the following; *looks like our female engineers just "disappear."* The caveat in current survey shows a relatively bleak picture of the future of female engineers despite the fact that schools in Johannesburg area are among the best in the country. In addition, statistics from the Engineering Board of Kenya indicate that 8.4% women are registered as professionals with the Board. This statistics is supported by the view that only 3% of female students in higher education choose to do ICT, 5% choose the natural sciences, mathematics and statistics stream whereas 8% select the engineering, construction and manufacturing stream (UNESCO, 2021). It is therefore clear that there is a gaping gender gap in science education that requires filling (Akala, 2024).

2. Theoretical Underpinning of the Study

Due to the complexity involved in gendering in STEM/science education, various theories and concepts were used to explore and address Gender Inclusivity in STEM Education. The discussions were guided by the Social Cognitive Career Theory (SCCT) by Lent et al. (1994). This theory takes into account external influences like social and economic factors, as well as individual cognitive factors, when determining career choices. It suggests that external environmental factors influence career decisions by affecting self-efficacy and outcome expectations, such as believing in oneself and developing an interest in one's work. These ideas are backed by Subotnik et al., (2019), who suggest that positive interactions with the STEM environment can boost students' self-efficacy, their perceived value of specific STEM fields, and ultimately influence their career choices. Also, according to Wang et al. (2020), self-efficacy and career perception play a significant role in shaping career interests. Environmental factors encompass physical and social conditions that form the basis for an individual's livelihood. According to Mohtar et al. (2019), school education, formal education, social support, and media can all influence students' STEM self-efficacy or career perception, which then influences their interest in STEM fields. The SCCT theory can offer valuable insights into understanding and promoting girls' interest and engagement in STEM education and fields.

By examining the nuanced effect of formal and informal learning experiences on students' interest in STEM careers, researchers can gain a deeper understanding of the factors that shape girls' perceptions and decisions regarding STEM fields (Wang et al., 2021). Moreover, SCCT can serve as a framework to explore how young women construct their identities through educational experiences, both in secondary and postsecondary settings (Green, n.d.). Understanding how girls author their identities in STEM fields can shed light on the challenges they face and the support mechanisms needed to encourage their persistence and success in STEM education and careers. Research examining the impact of formal and informal learning experiences on students' interest in STEM careers can provide valuable insights into the factors that influence girls' perceptions and decisions regarding STEM fields (Wang et al., 2021). Additionally, SCCT can act as a framework for investigating how young women shape their identities through educational experiences, both in secondary and postsecondary settings (Green, n.d.). Understanding how girls establish their identities in STEM fields can help to illuminate on the challenges they encounter, and the support mechanisms required to foster their perseverance and success in STEM education and careers.

Furthermore, scholars have demonstrated that Career Services departments in universities utilize SCCT to understand how students develop career interests and make educational and vocational choices (Thompson et al., 2022). By applying SCCT principles, educators and counsellors can customize interventions and support systems to empower girls in STEM and address barriers that impede their participation and success in these fields. In conclusion, the use of the Social Cognitive Career Theory in this study provides a comprehensive framework for investigating the factors influencing girls' interest, engagement, and persistence in STEM education. By examining the impact of learning experiences, identity formation, and career services through the lens of SCCT, researchers can develop targeted strategies to promote gender equity and inclusivity in STEM education and careers. The Social Cognitive Career Theory (Lent et al., 1994) which suggests that positive interactions with the STEM environment nurture and strengthen students' interest in STEM, boost their self-efficacy, and increase their perceived value of specific STEM fields, thus increasing the likelihood of pursuing a STEM career.

Claiborne (2021) argues that although current classrooms are more diverse and inclusive, science related injustices are predominantly experienced by minorities. Claiborne further notes that achieving justice in science begins with understanding and contextualising historical injustices, and how establishing classrooms that are socially just can avoid repeating mistakes of the past. The science community has excluded women, people of Color and members of the LGBTQI+ community from ownership of knowledge and inventions because they are seen as inferior. They were not credited for their work or research for the simple reason that it was not authored by White males (Dominus, 2019). A case in mind is the Marie Curie, a chemist from Poland who won the Nobel prize twice, for Physics and Chemistry. Although her work was ground breaking, she experienced sexism for her male colleagues who did not recognise her prowess in the field in equal measure with men.

Increasingly, a common argument feminist approaches to modern science is that it is part of a male- dominated culture. This culture enhances male dominance, and contributes to degradation of women's social position and their quality of life. Women in this field suffer triple marginalisation, of scientific racism, cultural prejudice and sexism. These forms of injustices are predicated on unfounded, nuanced and biased pseudoscientific beliefs and claims that allocate intelligence to a certain race, gender and group of people (Salter, Adams & Perez, 2018). We argue that the danger of advancing such unsubstantiated and tested discourses is that they promote epistemic injustices and exclusion to the affected groups (Fricker, 2016). Finally, we opine that development of capabilities is important for equitable human development (Akala, 2019). It bolsters societal and individual well being as argued by Sen (1993, 1995) and Nussbaum (1999). Therefore, addressing the perpetual gender gap in STEM will lead to a more inclusive and equitable society, benefiting individuals and communities.

3. The Leaking Pipes in Science Education

Some of the factors that perpetuate gender inequalities and exclusion in science education are well documented in pertinent literature. It is paradoxical that stringent patriarchal societies impose barriers to girls and women's education (Heybach & Pickup, 2017; Mkhize, 2021). Universities are traditionally viewed as spaces that are gendered- they reflect the social order of societies. In which case, O'Hagan et al (2016) aver that STEM career practices serve as mechanisms through which gender academic capitalism is produced and perpetuated. Even countries with positive gender equality figures still report a small number of girls and women in the STEM fields (UNESCO, 2021). Negative stereotypes- *boys are better than girls in maths and sciences* affects girls' confidence and tends to lower their performance and aspirations for careers in STEM fields (Wang et al., 2020). Of critical importance is the unconscious bias panacea- *maths and science are associated with men-* [*masculinity*] whereas women are inclined to study humanities which are linked to femininity- [nurturing and caring careers] determine career trajectories for girls and boys. Thus, the patriarchal equilibrium constrains girls' and women's development because, it fundamentally interacts with other systems of marginalisation (Akala, 2019, 2024; Robnett & Vierra, 2023). Framing of the gender problem in science education along masculinity is constructed early- in secondary schools. Kelly (1985) observed that the fluidity in science education is associated with, [difficulty, and hard, rather than soft, things rather than people, and thinking rather than feeling]. These factors are part and parcel of cultural stereotype of masculinity, and not femininity associated with societal gendered roles (Connell, 1999).

In hindsight, similar perceptions that advance the view that women in STEM are *less competent, less likable, non-conforming to gender and societal norms* negatively affect the likelihood of the uptake of science education and professions by girls and women (Mason et al., 2009; Mim, 2019). This concern calls for a gender neutral job spaces- where personal experiences and interests of individuals should be given preference (Mim, 2019). Familial roles and expectations in families and amongst peers significantly influence education choices of girls and boys. Underlying the choices, is the reinforcement of gender stereotypes. Feminism analysis renders itself to gender, and gender and science through the exploration of gendered choices STEM. Feminism perspectives indicate that gender as a performative practice structures relationships between masculinity and femininity- instead of it [gender] being seen as a natural essence which belongs to men and women. The second approach is linked to feminism gendered representation in science education- which skewed (Allegrini, 2014). Moving beyond the limitations of discourses of femininized science environments of [*gender washing and painting pink*] that do not yield meaningful engagement with scientific ontologies within scientific inquiry requires a critical framework that will disentangle gender from science (Heybach & Pickup, 2017).

Notwithstanding the above, women in STEM professions battle with the burden of family responsibilities (Dicke et al., 2019; Jean et al., 2014). In part, the leaking pipes in STEM professions are further propelled by a lack of balance between familial roles and work demands. Such women end up opting out/changing careers because they are the primary care givers in their families (Mason et al., 2009). In the case of South Africa, although there are more women than men in higher education (57%-43%), very few of them are enrolled in the STEM fields (Akala, 2019). In the same vein, it is concerning that women in the IT workforce are not being retained. Unfair remuneration practices, work-life imbalance, a toxic and non-inclusive company culture, lack of representation, unequal opportunities for growth, resistance and being underestimated, and the fast-paced and high demands of the industry contribute to fewer women in the field. Other challenges include the absence of female mentors and role models, inadequate recognition, and the lack of a technology background or exposure to technology from an early age (Kunda et.al., 2022). Efforts to boost women participation in STEM education and careers in South Africa have also been unsuccessful due to interpersonal factors such as [family and teachers]; intrapersonal factors- [champion mentality, career interest in STEM, personality, personal development, self-efficacy and spirituality] and finally, career outcomes expectancy factors – [finance, and career opportunities and prospects]. It is without a doubt that these factors contribute significantly [negatively or positively] to the students' career decision-making (Tandrayen-Ragoobur & Gokulsing, 2022).

Finally, learners/ students from historically disadvantaged groups are less likely to have access to advanced courses in STEM. Examples from America & South Africa indicate that students and learners [male and female] who attend schools with poor or non-existent facilities- labs, libraries, computer, electricity, connectivity, smartboards and trained teachers are largely disadvantaged in science education (Hill et.al, 2010).

4. Disrupting the Gender Gap in Science Education

Traditionally, given the consequences of gender skewing in STEM, several interventions have been suggested in literature. Addressing girls' confidence [lack thereof] in maths and sciences requires identifying the root causes of the impasse, and having targeted interventions aimed towards bolstering and restoring their confidence [self-concept] in science education. Literature suggests this could be linked to the behaviours, encouragement and attitudes of peers, parents, teachers and school counsellors [linked to Bronfenbrenner's Bioecological Model] (Rabenberg, 2013; Stout et al., 2011; Leaper & Starr, 2019; Hoffman, 2021). Reimaging the learning materials that promote gender stereotype and negative effect on girls and science education can lead palpable results. The Chilean grade 6 science textbook which had 6% characters that were female is a relevant example of learning material that does not promote gender inclusivity (Covacevich & Quintela-Dávila, 2014).

The scarcity of positive role models and mentors continues to deepen the gender gap in science education. Research shows that this can be alleviated by having a strong presence of successful women scientists to mentor the girls and women in schools and communities. Having positive female role models and mentors does not only assist in breaking the glass ceiling and revolving doors, but they also reduce the implicit stereotype [counterstereotypes] that science is masculine and not feminine (Young et al., 2013). Additionally, positive role models improve girls' beliefs of being successful in STEM fields, — and it also increases their likelihood of choosing a STEM career (Herman et al., 2016). In support, Solanki and Xu (2018) revealed that female teachers act as role models for female students and improve the female students learning engagement in STEM. UNESCO's STEM Mentorship Programme through Scientific Camps of Excellence in Kenya in 2014 has been successful in targeting secondary school girls in the country from rural areas. Besides, the AWUW report showed that teachers and parents play an important role in improving Maths outcomes for girls when they affirm girls by telling them that their [intelligence has the ability to expand with experience]. Thus, the report notes that- believing in the potential for intellectual growth, in and of itself, improves outcomes. Similarly, Sax et al (2018) suggest that students who were attracted to study biological science majors had parents in the same field and have aspirations to pursue doctoral studies.

Apart from mentors, content that supports and solves real life problems is seen as important catalyst that motivates girls to join STEM fields (UNESCO, 2021). Science teachers are also encouraged to adopt gender-responsive pedagogies that keep girls interested in the STEM subjects. Having access to mentors and content that supports and solves real life problems [making the nexus between scientific/abstract and everyday knowledge explicit is seen as important in motivating girls to join STEM field (UNESCO, 2021). STEM education not only addresses the different needs and aspirations of girls and boys but also challenges gender norms and wider societal inequalities (Crawford, 2020). Gender-transformative STEM education and teaching works towards making sure that learning materials are free from gender biases — it plays a key role in how girls experience science education. It engages women, men, girls and boys in critical thinking; examining and changing social norms and institutions that reinforce asymmetrical power relations. Gender-transformative education contributes to gender equality by considering possible impediments that perpetuate gender inequalities and unequal access to education opportunities (Chikunga, 2013; Müller & Bang-Manniche, 2021; Murphy-Graham, 2024).

Generally, the effects of discriminatory gender stereotypes and social gender norms, environmental factors, School based Gender Based Violence [GBV], sexual harassment and socioeconomic factors on access and success are considered (Müller & Bang-Manniche, 2021). We allude to the recommendation made by Mott

(2022) in a report dubbed *gender equity in Higher Education: Maximising Impacts of those Higher Education (HE)* -initiatives to support access to HE should not be skewed to STEM subjects- where male students dominate without Targeted Action to support women. In this case, we advocate for initiatives that will enhance access of women to STEM education in HE. A sociotransformative approach as an aspect of transformative education intervention targets the lived experiences of historically marginalized youth, and encourages researchers to focus on reporting research as *narratives of engagement* in order to bring about meaningful change (Rodriguez & Morrison, 2019). Consideration towards making learning environments friendly for diverse learners and students can help bolster gender equality in STEM (Hill et al., 2010; Vanner, 2025).

5. Conclusion

Considering gender inequalities in science education, we note that the important role formal and informal activities such as science congresses and internships play in informing how girls and women view science education. Using country and regional differences to address cultural believes, patriarchal and gendered assumptions and inclusive of women in all diversity in science education in equally advisable (Mott, 2022). Research has also demonstrated that, at the higher education level, interventions such as giving course overviews and introduction to courses have demonstrated an increase in uptake in STEM courses (Hill et al., 2010). Finally, a deliberate effort in the recruitment of teachers who are trained in gender responsive pedagogies -devoid of gender neutrality is necessary to keep girls and women in science education (Chikunga, 2013).

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