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Gender Gap in Science Education:
Pedagogical Implications in a Classroom in Secondary Schools in Tanzania

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ABSTRACT

There has been a prolonged tendency of the gender gap in interest, participation, and achievement in science worldwide. This article explored the gender gap in achievement of science; revisited the possible causes of gender gap in interest, participation and achievement in science; and revisited the suggested remedy measures in a science classroom. The information for the study was collected through a survey of a variety of 48 written sources. The study revealed that there is a significant gender gap in achievement in science in secondary schools in Tanzania. The responsible factors include male-oriented curriculum materials, patterns of classroom interaction, teaching, and evaluation; parents and teachers' lower expectations for girls' achievement in science; and socialisation of girls into dependence, nurturance, and passivity. The recommended solutions include the promotion of gender-responsive curriculum and practice.

KEYWORDS

Gender and Education, Gender and Science, Gender Gap in Science, Gender-Inclusive Education, Gender-Responsive Pedagogy, Secondary Education

INTRODUCTION

Science, mathematics, and technology are essential to every individual, including under-represented groups. This is because science, mathematics, and technology provide individuals with knowledge, skills, and attitudes essential to their everyday lives, as well as career opportunities. For instance, science increases agricultural and industrial productivity, and contributes to solutions to global challenges such as poverty reduction (Henriksen, 2015). Based on this significance, participation in science, mathematics, and technology education is essential for all children regardless of their differences, such as gender, ethnicity, class, or socio-economic status (Henriksen, 2015). According to Merayo and Ayuso (2022), reducing gender disparity in science and mathematics education can improve the labour market through increased employment and productivity among women and reduce

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job-related segregation. This study will focus on investigating the gender gap in science education in secondary schools, as research has revealed that the gender gap becomes more significant at this level, and that interest and participation in science decline with class level (age) (Barmby et al. 2008). Science in study is confined to biology, chemistry, mathematics, and physics subjects taught in secondary schools in Tanzania's education system. Gender equality is a concern at the international level. UNESCO has declared gender equality as one of the most important goals for education and ultimately incorporated this aim within the framework of sustainable development goals (United Nations 2018). The fifth of the United Nations' 17 Sustainable Development Goals (SDGs) aims to achieve gender equality and empower all women and girls (UNESCO, 2015). This can be achieved through inclusive practices in all areas of life, including schooling.

World-wide, there has been a prolonged tendency for girls' underachievement and under representation in science at various levels of schooling, mostly starting with the secondary school level (Lundberg, 2020; McDool & Morris, 2022; UNESCO, 2017). This inequality at lower levels of schooling becomes more evident in science related courses in higher education and in science related fields in the students' further occupations, favouring more males than females (Matete, 2022). Alexakos and Antoine (2003) assert that there has been a persistent gender gap in interest, participation, and achievement in primary and secondary science classrooms, the gap being critical in physics and chemistry subjects. Allegrini (2015) also observed that women continue to be under-represented in science, technology, engineering, and mathematics (STEM), especially in physics, mathematics, computer science, and engineering. ÇÇakiroglu (1999) highlights that sex differences exist at every grade level and in every subject area in the written science-related achievement tests, most of the time favouring males.

ÇÇakiroglu (1999) depicts the gender gap in international studies. The First International Science Study (FISS) in 1970 and 1971 was conducted in all countries. The Second International Science Study (SISS) was conducted from 1983 to 1984, involving 24 countries, and the 1995–96 Third International Mathematics and Science Study (TIMMS) was conducted among students in 41 countries at five different grade levels. In the first international study of 1970 and 1971, boys consistently performed better than girls in all countries. The gap increased as students ascended the school system and with age. Thus, the sex difference was shown to increase as students progressed through the school system and to be greatest for physics, somewhat smaller for chemistry, and smallest in biology.

In the Second International Science Study (SISS), the findings showed differences in science achievement favouring boys in biology, chemistry, and physics for all grade levels (5 to 12), although these differences were smaller than those reported from the first study (FISS) and were less consistent across countries. The TIMMS (1995–1996) observed that boys had significantly higher mean science achievement than girls at both the seventh and eighth grades internationally and in many countries. In the seventh, eighth, fourth, and third grades, gender differences in earth science, physics, and chemistry reflected advantages for boys. In Life Science, for the items covering environmental issues and the nature of science, girls and boys had similar performances at each grade. In life sciences, there were very few gender differences in average performance. Similarly, Martina (2021) reported the TIMSS results for students who took tests to assess their cognitive ability and educational achievement in both mathematics and science in 2011 in the countries of the European Union. The results showed that there was a smaller gender gap in cognitive achievement in science and mathematics during the early stages of education (fourth grade). The gender gaps became wider with increasing levels of education, and they were larger in the eighth grade. However, in Finland and Sweden, the gender gap in the eighth grade was in favour of girls. Meinck and Brese (2019), in their research on trends in TIMSS for 20 years, observed that the gaps that existed 20 years ago have persisted into the present. However, gender equality in education is increasing.

According to Masanja (2010), education statistics in Sub-Saharan African (SSA) countries show that women lag behind men in education in general, and particularly in science subjects, mathematics, and technology (SMT). Despite the enabling policy environment and other initiatives that are being implemented to promote women's participation and achievement in science-related subjects and fields, such as mathematics and technology, female students continue to lag behind, especially in tertiary levels, where girls' participation, completion, and achievement rates are lower (Masanja, 2010). According to the Tanzania country gender profile for the year 2016, gender parity in education has been successfully achieved in pre-primary and primary education. However, it rises sharply when moving to secondary and higher education. (URT 2016a), the government stipulates that:

Each year, there have been outstanding performances by female students in both Form IV and Form VI. However, male students perform better in science subjects than female students. The fact that the completion rate of females in lower secondary education is lower than that of males indicates that more females are entering the labour force with lower qualifications than males (URT 2016a, p. 78).

Similarly, Hamilton et al. (2010, p. 6), under the UNESCO needs assessment study of Tanzania's science education, presented the gender gap in science that existed in performance in the Certificate of Secondary Education Examination (ordinary-level secondary education examination results) for the years 2005 to 2009. His results had shown that for five years, girls' performance in the Certificate of Secondary Education Examination in Mathematics and Science subjects (Mathematics, Biology, Chemistry, and Physics) was below that of boys.

This trend poses a concern for research to address the gender gap between boys and girls. Allegrini (2015) observed that attitudes towards science and school types (single-sex or mixed) affect the students' choice of science. For instance, misconceptions such as that science is difficult, uncreative, and a socially isolating pursuit make students leave science subjects (Masnick et al. 2010). Moreover, the choice of science by girl students from single girl schools is higher than for mixed schools (Allegrini, 2015). However, according to Tytler and Osborner (2012), the quality of teaching is a major determinant of student engagement and success in science. The gender gap in science appears to be a serious problem because it is reported that the countries characterized by gender equality, such as Finland, Norway, and Sweden, have wider gaps in science than the countries that rank poorly in gender equality; this has been described as a gender-equality paradox (Stoet and Geary 2018). In most sub-Saharan African countries, much effort has been geared towards promoting gender equality in schooling in terms of access and completion rate, while less attention has been paid to gender-biased classroom practices that affect inclusion in the teaching and learning of science (Mwakabenga & Komba, 2021). Therefore, along with other government efforts, including combating gender discrimination and violence and building separate science secondary schools for girls, there is an urgent need to pay attention to the quality of science learning in the classroom context. Mwakabenga and Komba (2021) observed that some teachers promoted gender inequalities consciously or unconsciously, a habit that emanated from their preconceptions and limited knowledge of gender matters. Kinyota (2021) commented that meanings associated with science are in conflict with meanings associated with being a woman; girls must struggle to find a negotiating space by balancing the two conflicting identities. The process of removing stereotypes from textbooks, improving teaching methods, and introducing teachers to gender-sensitive classroom interactions has been reported since 2005 (URT, 2005). However, not much has been explored about gender-responsive pedagogy in Tanzania. The purpose of this article is to promote gender-responsive pedagogy in the context of Tanzania.

Purpose of the Study

The scope of this paper centres on investigating the gender gap in interest, participation, and achievement in science (physics, chemistry, biology, and mathematics) in Tanzania and what can be done in a science classroom in secondary schools to minimize the gender gap. This paper aims at putting forward an initiative for gender-responsive pedagogy in science education. The study specifically focuses on:

1) Examining the gender gap in Certificate of Secondary Education Examination (CSEE) performance in science subjects in ordinary-level secondary schools in Tanzania;

2) Investigating factors affecting girls' interest, participation, and achievement in science; and
3) Exploring the strategies that can be used in a science classroom to minimize the gender gap in interest, participation, and achievement in science in secondary schools.

Research Questions

This study was guided by the following research questions:

i. How wide is the gender gap in Certificate of Secondary Education Examination (CSEE) performance in science subjects in ordinary-level secondary schools in Tanzania, if any?
ii. What are the factors affecting girls' interest, participation, and achievement in science?
iii. What are the strategies that can be used in a science classroom to minimize the gender gap in interest, participation, and achievement in science in secondary schools?

REVIEW OF THE LITERATURE

Theoretical Framework

Gender-responsive pedagogy refers to teaching and learning process that pays attention to the specific learning needs of girls and boys (FAWE, 2018). It considers gender in lesson planning, teaching and learning materials, pedagogical approaches, classroom design, and learning infrastructure in the classroom. Most characteristics of gender-responsive pedagogy were found to be pertinent to liberal feminism and constructivism theories. This study is guided by two theories, namely, liberal feminism and constructivism. This is because the investigation is dealing with classroom practices that are likely to bridge the gender gap in a science classroom. It has been observed that girl students prefer cooperative learning to individualistic and competitive approaches to learning (Elechi, 2010). More importantly, the pedagogical approaches proposed by these theories are similar in several respects. Both theories require the diminishing authority of the teacher and encourage interaction in the classroom, leading to transformative learning. Pedagogical approaches that are top-down and teacher-centered can result in student passivity and conformity (FAWE, 2018).

Liberal Feminism

Liberal feminism is a traditional perspective that was established as a part of the first wave of feminism and is against the belief that women are, by nature, intellectually and physically weaker than men (Tong, 2009). The gender gap is a consequence of the genderisation process imposed by society. The liberal feminist theory is founded on three main assumptions (Ropers-Huilman, 2003). The first principle is that women have something valuable to contribute to every aspect of the world. Secondly, as an oppressed group, women have been unable to achieve their potential, receive rewards, or gain full participation in society. Thirdly, feminist research should do more than critique; it should work toward social transformation. Apart from dealing with violence against women, raising women's health status, and ensuring female voices are heard, feminism is also concerned with education, intellectual development, and opportunities for women (Cofey & Delamont, 2000). Coffey and Delamont (2000) argue that feminism is still relevant as a way of thinking about the social world and as a lived reality.

Constructivism

The constructivist paradigm is based on the assumption that knowledge is subjective and that learners construct knowledge in the social and cultural environment in which they are embedded. The underlying principles of constructivism can be traced back to the learning theories of John Dewey (1933), Jean Piaget (1983), and Jerome Bruner (1961). They believed that learning could only occur to the extent that new information linked successfully with a learner's prior knowledge and experience.

The Russian psychologist Vygotsky (1978) added the view that learning is greatly enhanced by collaborative social interaction and communication. In other words, discussion, feedback, and the sharing of ideas are powerful influences on learning. While Piaget (1973) suggests that learners construct knowledge individually, Vygotsky (1978) emphasizes that social interaction is important for the construction of knowledge.

In a constructivist classroom, the teacher assumes the role of a facilitator and guide. The teacher becomes the manager, not the controller, of the class. Students take responsibility for their own learning. The question, state problems, design experiments, and discuss their results with others. The Government of Tanzania, through its then Ministry of Education and Vocational Training, has adopted a competency-based curriculum approach since 2006 for primary and secondary education. The competency-based curriculum requires a shift from behaviourism theory of learning to constructivism, teacher-centred to learner-centred teaching and learning methods, emphasis from content to competence, knowledge inheritance to knowledge construction, product-oriented to process-oriented, end-of-lesson evaluation to classroom assessment, and memorization of facts to the development of higher-order thinking skills (Mrimi, 2010). There is a need for a change from objective, standardized tests to performance-based tests.

RESEARCH METHODOLOGY

This study used a mixed-methods design whereby quantitative and qualitative approached have been employed. The first objective of the study used some descriptive statistics, including tables and histograms for secondary data drawn from the Certificate of Secondary Education Examination (CSEE) drawn from national reports. The data were used to examine the gender gap in CSEE performance in science subjects in the final ordinary-level secondary schools in Tanzania. For investigating factors affecting girls' interest, participation, and achievement in science and exploring the strategies that could be undertaken to minimize the gender gap in interest, participation, and achievement in science in secondary schools, a literature review was supplemented by an informal interview with eight girl students who are studying bachelor of education in science at one of the universities in Tanzania. The interviewees were first-year students who had just joined the university from secondary schools. Hence, the students were asked to share their lived experiences during their schooling in secondary schools. Eight (8) Tanzania national reports, eight (8) books, twenty-nine (35) journal articles, five (5) book chapters, three UNESCO reports, one World Bank report, one Population Council-Regional Education Learning Initiative report, and two (2) theses relevant to study objectives were reviewed. The information for the study was collected through a survey of the variety of written sources and the identified relevant observations were synthesised to the research problem to contribute to the existing body of knowledge and understanding of the gender-responsive pedagogy in science education in the context of Tanzania.

RESULTS AND DISCUSSIONS

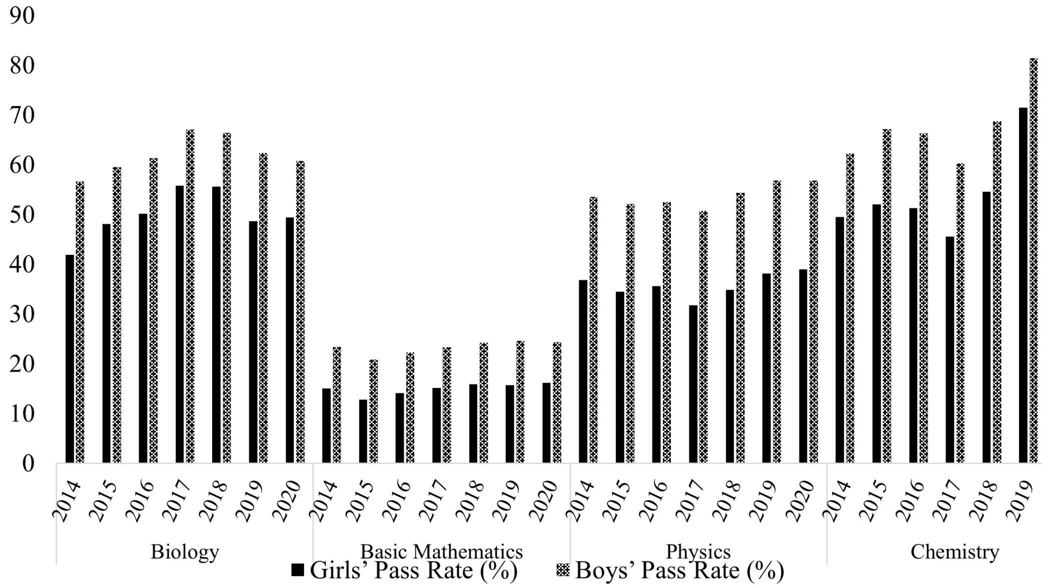
The Status of Gender Gap in Performance in Tanzania

Figure 1 shows the trend of the gender gap in ordinary level secondary education in science

Subjects (Physics, Chemistry, Biology, and Mathematics) in the Certificate of Secondary Education Examination (CSEE) for the years 2014 to 2020 by URT (2016b, 2019, 2020, and 2021). The data show that the girls lagged behind the boys in pass rates in all the science subjects as well as mathematics. The pass rates were computed from the number of candidates who sat for the examination for the given subject divided by the number of students who passed the examination, separately for boys and girls. These results are similar to those provided by Hamilton et al. (2010). However, in these new findings, the gender disparity has been critical in physics subjects, followed

Figure 1. CSEE pass rates for girls and boys 2014 – 2020

Sources: *The United Republic of Tanzania, 2016b, 2016c, 2018, 2019, 2020 & 2021)*



by chemistry and biology. In the study by Hamilton et al. (2010), the gender disparity appeared more or less equal across all the subjects.

Table 1 shows the gender disparity (gap) in pass rates between boys and girls in the CSEE in each subject for the five years from 2014 to 2020. The disparity was obtained by subtracting the pass rate of girls from the pass rate of boys for each subject. The disparity was critical in physics, as it ranged from 16.7 to 19.5; this was followed by chemistry, whose disparity ranged from 6 to 15.1, biology, from 10.8 to 11.5, and basic mathematics, whose gender disparity ranged from 8.1 to 9. Although the performance in mathematics was the lowest, the gender disparity was the lowest. These results are similar to the findings of Alexakos and Antoine (2003), who observed that the gender gap in secondary science classrooms was critical in physics and chemistry subjects.

Factors Affecting Girls' Interest, Participation, and Achievement in Science

The following are the factors that have been attributed to a gender gap in Science education:

- Gender stereotyping;
- Male oriented curriculum materials;
- Male oriented patterns of classroom interaction;
- Masculine expressions and images in some of the curriculum materials;
- Masculine expressions by teachers when implementing the curricula;
- Parents and teachers' lower expectation for girls' achievement in Science;
- The socialisation of girls into dependence, nurturance, and passivity;
- The dominance of competitive teaching strategies rather than cooperative strategies in a classroom; and
- The nature of the test as well as the types of test items in Science does not favour the girls.

Table 1. Gender disparity in pass rates for science in the certificate of secondary examination 2014 – 2020 for boys and girls

Subject	*Year*	*Gender Disparity*
Biology	2014	15.2
	2015	11.5
	2016	11.2
	2017	11.3
	2018	10.8
	2019	13.7
	2020	11.4
Basic Mathematics	2014	8.3
	2015	8.1
	2016	8.2
	2017	8.1
	2018	8.4
	2019	9
	2020	8.2
Physics	2014	16.7
	2015	17.7
	2016	16.9
	2017	19.0
	2018	19.5
	2019	18.7
	2020	17.9
Chemistry	2014	12.8
	2015	15.1
	2016	15
	2017	14.7
	2018	14.2
	2019	10
	2020	6

Data Sources: The United Republic of Tanzania, (2016b, 2016c, 2018, 2019, 2020 & 2021)

These sub-themes can be integrated into four sub-themes: gender stereotyping, the prevalence of competitive teaching strategies, the nature of the tests, and teacher classroom practices. The discussion extends to the effect of COVID-19 in secondary education and gender problems. Before discussing the themes, it is important to keep in mind that biological differences have no influence on the gender gap. According to Ceci and Williams (2007), modulation, human cognitive development, and human evolution have found no significant biological difference in men's and women's ability to perform in science and mathematics. Blickenstaff (2005) points out that there is no link between brain size and intelligence, as researchers realized that when corrected for overall body mass, men and women have brains of equal size. Blickenstaff (2005) came to the conclusion that:

It seems clear from the literature that whatever biological differences there are between men and women, there is very little difference in scientific or mathematical ability, and certainly not enough to explain the under-representation of women in STEM careers. There is a danger in continuing to emphasize biological differences between men and women because the tendency is to then argue that if unalterable biological differences exist, then no action needs to be taken to improve the situation for women (Blickenstaff, 2005, p. 372-373).

In contrast, Allegrini (2015) asserts that female and male biological attributes have been used to assign gender roles to men and women. Hence, gender highlights the sexed processes through which society perceives and represents human beings through sexed relationships (Allegrini, 2015). As a consequence of this process, science has been generally perceived as a male-dominated field. This perception is also affecting women's participation and achievement in science. Kahle and Meece (1994) and Çakiroglu (1999) point out that the main factors contributing to the differential interest, participation, and achievement of boys and girls in science include opportunities to learn, gender stereotypes, and curriculum orientation and implementation. The factors affect interest, participation, and achievement not separately but in an integrated manner.

Gender Stereotyping

Lundberg (2020) observed that the social influence of family, peers, and role models on attitudes toward science and mathematics fields reflects norms in which these subjects are masculine and unfeminine. Hence, the girls' competence in science and mathematics is considered low. Interviews with the female student teachers revealed that boys as well as girl students did not expect the girl students to perform well in science and mathematics. For instance, one of the interviewed student teachers, when asked what challenges she did face while schooling in secondary school, said,

As I used to perform well in science and mathematics to the point of outperforming some boys. Some of the boys were not comfortable with the situation. I was chastised and even bullied at times. Generally, they took ill of me through gossip. (Interview with Student-Teacher D, May 15, 2023)

The previous quotation shows that good performance for girls in mixed-sex secondary schools was not expected by the students. Consequently, when a girl performed well in science or mathematics, she was faced with scolding and bullying from fellow students. Keller (1985) points out some main stereotypes that are leading to science being gendered. There is a stereotype that objectivity and rationality are considered to concur with masculinity, whereas subjectivity, irrationality, and emotionality are considered female attributes. Consequently, philosophy and science are considered neutral human activities free from personal and affective connotations and are therefore associated with masculinity. At the same time, other disciplines that are considered artistic intuitions and creative practices have been associated with femininity. This also causes bias towards males in the way in which curriculum materials are presented and packed, to the extent that the classrooms are dominated by male-oriented patterns of classroom interaction that discourage girls from active participation (Cofey & Delamond, 2000; Keller, 1984). Gender stereotyping has led to the use of masculine expressions and images in some of the curriculum materials and teachers' practices when implementing the curricula. In an interview with one of the science education student-teachers, she said:

Sometimes the language used by some of our teachers in a science classroom was offensive to us as girls. For instance, in higher secondary school, one day our science teacher entered our classroom and said that he could see all the boys in the classroom, in a class that had a mixture of girls and boys. Although it was a joke, we girl students felt offended by that kind of language. (Interview with a science student teacher C, May 16, 2023)

The quotation shows that the teachers mocked the class, saying that it was composed of only boys while it was a mixed class. This shows that some science teachers have been using gender-sensitive language, which has offended girl students who are undertaking science and mathematics subjects. There is a stereotype that girls who study science and mathematics behave like boys and show some masculine characteristics. This is likely to have been a consequence of gender stereotyping. Cofey & Delamont (2000) report that there has been a dominance and acceptability of male-defined models of language practice and use in the science curriculum.

Kahle and Meece (1994) and Çakiroglu (1999) point out that parents, as well as teachers, are reported to have a lower expectation for girls' achievement in science. Thus, parents and teachers demonstrate less faith in girls' abilities than they do in boys' abilities, causing girls to lose their sense of academic self-esteem as they grow. This, in turn, leads to less encouragement, stimulation, and opportunity to explore scientific phenomena at home and school for girls. In addition, socialization in the home and school discourages girls from developing the characteristics that have been associated with those of scientists, including independence, convergent thinking, logic, and experimentation, as girls are often socialized into opposite characteristics such as dependence, nurturance, and passivity. Parents structure the social and physical environment for boys and girls differently and tend to buy more scientific games and toys for their sons than for their daughters. Allegrini (2015) points out that girls' disengagement in science began earlier, from home to earlier school years. The trend continues. Visits to science museums, science activities associated with scouting, and enrolment in extracurricular science classes are more common among boys than girls.

Dominance of Competitive Strategies at the EXPENSe of Cooperative Strategies

According to the NEMO Science Learning Centre (2015), the levels of the hormones oxytocin and testosterone determine the motivational means. Testosterone makes men want to compete with others. Hence, competition is a good motivator for boys. While females have higher levels of oxytocin, which stimulates them to establish relationships with and please others, Thus, female students prefer cooperative learning. Contrary to popular belief, science teachers do not give them opportunities to carry out tasks equally with the males in order to learn cooperatively (Elechi, 2010). Thus, there has been an emphasis on competition rather than cooperative strategies. Martin (2017) observed that in many low-income countries, teachers view students as deficient and not capable of participating in learning tasks. This leads teachers to resort to passive engagement and rote memorization, which in turn leads to the development of lower thinking skills. Sadker and Sadker (1982) and Grayson (1988) investigated teacher-student interaction patterns and found that some teacher behaviours provided more instructional time to male students than their female counterparts.

Nature of the Tests

Çakiroglu (1999) also points out that the nature of the test as well as the types of test items used to assess achievement in science do not favour the girls. It has been observed that males on average score higher on objective tests, whereas females as a group score better on essay tests. Furthermore, many test items contain references to games, sports, and means of transport such as cars, ships, and air-planes, as well as other activities that are based on boys' interests (e.g., baseball averages, motorcycle mileage, and auto-mobile engines). The use of masculine expressions and images in the curriculum and in curriculum materials and practices portrays the masculine nature of science. (Cofey & Delamont, 2000) observed that the adoption of 'masculine' words and terms as universal, such as 'he', 'man', 'master," and so on, in the curriculum leads to the genderisation of science. In addition, the presence of more male teachers and boy students in science portrays masculine images in science that might be affecting girls' choice, interest, participation, and achievement in science.

Teachers' Classroom Practices

An empirical study done on strategies for closing the gender gap in science and technology classrooms in Nigerian secondary schools, where teachers' perceptions of gender mainstreaming were examined, was done by Ngozi and Kalu-Uche (2013). The scholar observed the activity and passivity in relation to boys and girls; teachers' beliefs on intellectual capacity between girls and boys; corrections and reprimands given to boys as compared to girls; attention given to girls as compared to boys; and the type of tasks given to boys and girls. The following were observed: When practical activities were performed, boys were more actively involved than girls; most teachers believed that boys were superior to girls in relation to mental ability or intellectual capacity, and boys were more energetic than girls; boys were reprimanded more often than girls; teachers gave more attention to boys than girls; and difficult tasks were given to boys to perform while easy tasks were given to girls to perform. One science student teacher had this to say with respect to this argument:

Our science teachers and boys held the belief that we girls were not smart at science and mathematics. Due to this belief, most girls felt inferior, such that they avoided working on difficult tasks and attempted fewer exercises compared to boys. This made the boys maintain their performance, while the girls' performance was low. (Interview with a student-teacher A, May 15, 2023)

This observation shows that teachers and students have false assumptions that boys are intellectually stronger than girls with respect to science and mathematics. This makes the teachers lack patience and enthusiasm when dealing with girls learning needs. This belief lowers girls' self-efficacy and causes them to develop anxiety about science and mathematics.

The Government of Tanzania, through the Ministry of Education and Vocational Training, had by then adopted a competency-based curriculum approach in secondary education. This replaced the content-based curriculum, which was implemented at the primary school level (Hamilton, Mahera, Mateng'e, & Machumu, 2010). If this could have been implemented well in schools, the problem could have been significantly reduced. However, resources are lacking in several aspects of education, including insufficient numbers of qualified teachers of mathematics and science subjects, inadequate equipment and materials, textbooks, and facilities (i.e., laboratories and libraries) (Hamilton et al. 2010). In the national gender profile, the government reveals that:

Inadequate resources are affecting the quality of schools' infrastructure and impacting the status of female students more than that of male students. Poor facilities and a lack of a conducive environment for teaching and learning in many schools are demoralizing students and teachers (URT, 2016a, p. 15).

With reference to this, five of the eight student-teachers interviewed attributed the low performance of science and mathematics to a shortage of science and mathematics teachers. One of the student-teachers said:

We had a few science and mathematics teachers compared to the number of students. We were many students with few teachers. It was difficult for the teachers to identify individual learning difficulties and apply appropriate remedies. (Interview with Students, Teacher H, May 15, 2023)

In accordance with the secondary school statistics provided in 2016 with reference to Tanzania, there is an acute shortage of teachers in mathematics, physics, chemistry, and biology subjects as compared to other subjects (URT 2016b). In addition, teachers have not been sufficiently oriented to the new curriculum pedagogical requirements, including competency-based curriculum and gender-inclusive pedagogy. There are also not enough curriculum materials to guide teachers in the implementation of the competency-based approach (Kafyulilo et al., 2012; Mafumiko, 2006).

Hence, the curriculum is not implemented as intended (Hamilton, 2010; Kinyota, 2020). Teachers in Tanzania prefer to use teacher-centred pedagogy (Kafyulilo & Tilya, 2019; Kinyota, 2020). Kinyota (2020) observed that there are challenges such as larger class sizes, insufficient time allocation, and an overemphasis on content coverage that need to be addressed in Tanzania.

The Effect of COVID-19 in Secondary Education and Gender Problems

According to Msigwa (2020), in Tanzania, the first person was announced to have COVID-19 on March 6, 2020. On March 17, 2020, the government announced a national-wide closure of all schools for an unknown period. The closure of schools lasted for about four months. The modes of delivery used during school included radio broadcasting, television broadcasting, the use of mobile phones, social media (WhatsApp, Twitter), tutoring, and on-line learning (Msigwa, 2020). However, Daniels (2021) observed that under such digital modes of delivery, girls were exposed to cyber-harassment. The author reports that the lock-downs and school closures were associated with gender-based violence, early pregnancy, and early marriage. Moreover, when girls remain at home, they are likely to be involved in domestic chores and nurturing services, and they may even be subjected to child labour. There also exists a digital divide among girls and boys in favour of boys in digital literacy.

Strategies for Minimising the Gender Gap in Science

In exploring the strategies that can be used in a science classroom to minimize the gender gap in interest, participation, and achievement in science in secondary schools, the following strategies were highlighted by most of the literature:

- Use of teaching strategies that promote cooperation rather than competition;
- Avoid Gender Stereotypes
    - Use of gender-inclusive languages or expressions;
    - Use of gender-inclusive images, pictures and textual materials; Use of gender-inclusive teacher-student interaction in S&T classrooms;
    - Eliminating/avoiding behaviours or utterances that are gender-sensitive;
- Provide examples and illustrations that are of interest to both girls and boys;
- The tests items should be associated with girls' needs and interests as well as boys;
- Transformation from emphasis from assessment of learning to assessment for learning; and
- Sensitise the students about gender issues through discussions in the classroom.

These sub-themes are integrated into four themes that include: promotion of teaching strategies that promote cooperation; avoidance of gender stereotyping; and promotion of assessment for learning. According to Antoine (2003), the classroom environment plays a primary role in cultivating self-efficacy. A sense of belonging, the relevance of tasks, laboratory experiences, curiosity, humour, and fun all contribute to classroom interest (Antoine, 2003). Okeke (2008) recommends the alteration of materials, pedagogies, ideologies, and practices among learners and teachers. Blickenstaff (2005) supports the idea that some of the reasons girls express discomfort with science can be addressed by altering curriculum materials and pedagogy.

Promotion of Cooperative Teaching Strategies

Okoli (2012) proposes the use of teaching strategies that promote cooperation rather than competition. White and Frederiksen (1998) argue that a cooperative learning environment creates a more positive attitude when students see others similar to themselves overcome difficulties successfully. Individualized instruction decreases social comparison and nurtures self-comparison, raising perceived self-capability.

In addition, cooperative strategies have been associated with enhanced interest, participation, and achievement for girls. In the interview with the science education student-teachers, one of the student teachers (G) attributed her good performance to cooperative learning strategies reinforced by their teachers. She has this to say:

Our teacher formed permanent groups of students with mixed sex and abilities who were to study cooperatively during learning science and mathematics. During tests, the group whose individuals had a great deviation in performance was punished. The student with the higher score received greater punishment. The student with the lowest score received the least punishment and was used as a case study to diagnose the learning difficulties and apply the remedial measures to the group. This strategy helped us all do well in science. None of us failed the final examination. (Interview with student-teacher G, May 16, 2023)

The previous quotation shows that the teachers formed permanent learning groups in which individuals were guided to support each other in learning science and mathematics. This strategy reduced competition and encouraged cooperation.

Similarly, Ford and Mullennix (2016) interviewed male and female students to suggest what teachers could do to make STEM courses more engaging and interesting. Being active in interactive activities (having hands-on activities) was the general response. Hence, students want to be a part of the learning experience. Hesse-Biber & Gilbert (1994) proposed the use of cooperative strategies such as games, simulations, role-play, group discussion, career-oriented teaching, and the use of small groups during practical science classes. A cooperative learning environment creates a more positive attitude when students see others similar to themselves overcome difficulties successfully. Individualized instruction decreases social comparison and nurtures self-comparison, raising perceived self-capability. Merayo and Ayuso (2022) draw the conclusion that girls get interested in science and mathematics when more emphasis is put on the applications of the theories and when they are involved in hands-on activities. Martin (2017) asserts that feminist pedagogy requires constant exchange and interaction between teachers and students and constant critical reflection. Maltese and Tai (2010) report that classroom and school experiences such as science competitions, science camps, teacher demonstrations, and project work promote interest, participation, and achievement in science. Classroom teachers need to actively encourage female involvement and participation. Alexakos and Antoine (2003) and Okoli (2012) recommend the use of gender-inclusive teacher-student interaction in a classroom: A gender-inclusive classroom is one where equal opportunity is provided for male and female students to interact with their teacher as well as among themselves. Through interaction, students transform from knowledge consumers to knowledge producers (Freire, 1970) as they become engaged in active learning and become social change agents (Ochoa & Pershing, 2011).

Avoid Gender Stereotyping

Ngozi and Kalu-Uche (2013) suggest that the use of gender-inclusive languages or expressions, such as the use of masculine nouns and pronouns to refer to both males and females, should be avoided in science and technology classrooms. It is recommended to use humankind instead of mankind, human being in place of man (to refer to males and females), and chairperson instead of chairman. Okoli (2012) encourages the use of gender-inclusive images, pictures, and textual materials, as well as girl-friendly curricular materials that can enhance girls' participation and performance in science and technology classes. Okoli (2013) advises teachers to avoid behaviours or utterances that are gender-sensitive in science and mathematics classrooms, such as the use of jokes or behaviours that negatively impinge on the personalities or cultural roles of male and female students. The scholar argues that teachers need to know their students for the purpose of correcting the biases, inferiority, and stereotypes that students hold. In an interview with the science education student teachers, one student (student E) said:

Girl students need to be empowered from early childhood education through primary and secondary schools to higher education. More attention should be paid to them to involve them in learning activities and leadership positions. These strategies would instil self-confidence among them and slowly undo the negative perception that has resulted from stereotyping among other students and teachers. (Interview with girl student E, May 15, 2023)

The previous quote suggests that girl empowerment in science and other aspects needs to start earlier in school life.

Promotion of Assessment for Learning

Instructors need to encourage students to concentrate on how the right answer is determined and not just on what the answer is. The emphasis on 'right' and 'wrong' should be discouraged, and the emphasis should be given on justification for why one answer is plausible and not the other one. Moreover, comparing students based on test results should be discouraged, such as by calling some kids smarter than others. This will de-emphasize individual weakness as well. Instead, the focus should be on providing more focused meta-cognitive activities, which can be beneficial to both low- and high-achieving students (White and Frederiksen 1998). A cooperative learning environment creates a more positive attitude when students see others similar to themselves overcome difficulties successfully. Individualized instruction decreases social comparison and nurtures self-comparison, raising perceived self-capability.

Most of the student-teachers interviewed attributed their good performance in secondary schools to many exercises and tests, including monthly tests, weekly tests, and fortnightly tests. The tests were mainly used to diagnose students learning difficulties and make appropriate remedies. There is a need for transformation from the emphasis on assessment of learning to assessment for learning and as learning, from criterion-referenced testing to norm-referenced testing. Similar to other countries, in Tanzania, there is a problem of an examination-driven education system where teaching is centred on helping students pass examinations rather than mastery of knowledge, skills, and values (Mhando, 2012; Nyirenda and Ishumi, 2004; Sumra & Katabaro, 2014).

The nature of the examinations that we have is distorting learning objectives to focus on aspects that are not the skills and capabilities we desperately need, and we begin to believe that we are doing better when, in fact, we are not (Sumra & Katabaro, 2014, p. 31).

Therefore, feminist pedagogy, as proposed by Conrad et al. (2011), requires learning to be viewed not as a product but as a lifelong process of continuous transformation. The students should be treated by a teacher as fellow learners who are actively involved in constructing knowledge in a classroom. Moreover, education should challenge, not reinforce, unquestioned norms and injustices in society, and theory and practice are interconnected; hence, they should be integrated and not separated. With the problems that were associated with digital learning. Msigwa (2020) recommends that on-line learning is the most effective way due to its interactivity. In addition, schools need to develop some means of cooperating with parents and supporting their involvement in their children's home-based education (Daniels, 2022). Tanzania initiated the Education Sector Development Programme (ESDP) for the revitalization of and improvement of the delivery of secondary education. Among others, one of the objectives is to expand and improve girls' education. However, the strategies for achieving this objective are less clearly stipulated (Hamilton et al., 2010). This study is aimed at sparking classroom strategies in an attempt to close the gender gap. The government also recognized that there is a need for emphasis on gender-responsive pedagogy, as in the country gender profile of 2016, which also recommends the improvement of gender-sensitive pedagogy that may encourage girls to participate and excel in science (URT 2016a).

CONCLUSION

There exists a significant gender gap in interest, participation, and achievement in science (including mathematics) in ordinary-level secondary schools. The quality of teaching is a major determinant of student engagement and success in science. The predictors of this trend, as reviewed in the literature, include gender stereotyping in curriculum orientation and implementation, the prevalence of competitive teaching strategies, and the nature of the tests that mostly favour boys. There is a need for alteration in pedagogy in terms of materials, ideologies, and practices in the science classroom. It is necessary to pay attention to gender biases present in the curriculum materials, such as images and expressions, and make the appropriate modifications. Girls prefer cooperative teaching strategies to competition. Girls also want to see how the knowledge they learn can promote their motivation to help others and the community. The science and mathematics curriculum orientations and implementations must emphasize cooperative learning, include more applications of the theories learned, and involve more hands-on activities.

There is a need to recruit more science, mathematics, and science teachers, increase laboratories and laboratory equipment and apparatus, and review the curriculum materials to see how they respond to both gender needs. In addition, teachers have to have been oriented to gender-responsive pedagogy and other new curriculum pedagogical requirements. This can be done through pre-service and in-service teacher training. It has also been observed that teachers encourage boys more than girls in a classroom. Thus, girls need to be encouraged to participate in science and mathematics by making these subjects attractive to them and increasing their self-esteem. It is therefore recommended to provide more curriculum materials and guide teachers on the implementation of the competency-based approach and gender-responsive pedagogy. When female students become successful in science-related subjects, it is possible for them to continue with science in the higher classes; previous science performance is the main predictor of choosing science in the higher classes. Moreover, there is a need to work with the digital literacy gap among girls and boys in order to enhance digital learning. Teleconference is the most effective method of on-line teaching due to its interactivity. Parents need to be educated on how constructively they can support their children's home-based education. There is a need, in Tanzania and in other sub-Saharan African countries, for classroom-based research on teaching strategies and materials that can include girls in science education.

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