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Environmental factors influencing girls' participation in science education in Tanzanian secondary schools

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Abstract. This paper examines the environmental influences on girls' participation in science education in Tanzanian secondary schools. A multiple qualitative case study research design was adopted to capture the experiences of 40 participants involved in the teaching and learning processes. Data analysis followed Braun and Clarke [8] six stages of thematic analysis. Findings from observations, interviews, focus group discussions, and documentary reviews indicated that girls faced different environmental challenges, resulting in their poor participation in the related fields. However, teachers improved the participation of girls in science by creating a conducive learning environment by providing personal advice, creating a friendly learning environment, providing girls with opportunities to learn, using motivational techniques, and building confidence in girls in science. The study recommends collaborative efforts to improve girls' participation in learning the subjects. In addition, a larger sample investigation should be conducted to understand better the situation in different educational settings in the country.

Keywords: environment, girls, science

1. Introduction

The environment is an inseparable aspect of human life, profoundly influencing daily activities and playing a pivotal role in the teaching and learning of Science, Technology, Engineering, and Mathematics (STEM) subjects [53, 92]. Effective STEM education cannot occur in isolation; it requires the deliberate incorporation of environmental considerations into both teaching and learning processes [92]. The environment provides essential context and relevance, making learning experiences more meaningful and directly connected to real-world situations. A conducive learning environment encompasses physical, cognitive, affective, and social elements that collectively facilitate effective learning [51]. These attributes are crucial for fostering an atmosphere where learners feel motivated to acquire skills and knowledge in their respective disciplines [51]. Furthermore, by integrating environmental components in teaching and learning processes, teachers can enhance students' understanding of how their knowledge applies to real-world situations, thereby preparing them to contribute meaningfully to society's challenges [79].

Science, Technology, Engineering, and Mathematics (STEM) education is increasingly recognised as a crucial framework for addressing complex societal challenges [34]. STEM education not only empowers individuals with critical problem-solving skills but also cultivates creativity and innovation, which are essential for the sustainable socio-economic development of nations [36]. As technology continues to evolve and play a pivotal role in various industries, the opportunities within STEM careers are expected to expand significantly. This trend underscores the increasing demand

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for professionals equipped with skills in these areas, emphasising the importance of fostering interest in education, particularly in STEM disciplines, to meet future workforce needs [88]. Recent studies have highlighted that STEM-related careers are experiencing significant growth compared to other fields [66, 94].

Despite increasing recognition of the importance of STEM education, there is concern that student participation in STEM, particularly among girls, continues to decline as they progress to higher levels of education [32, 76]. This trend underscores a significant challenge in achieving gender equity in fields that are crucial for future innovation and economic growth. Furthermore, the underrepresentation of girls in STEM fields poses significant challenges for their future participation in the labour market, which increasingly requires STEM skills [41, 71, 78]. This issue has persisted over time, with regional variations in its impact [11, 28].

According to UNESCO reports, women comprise only 35% of STEM students in higher education globally, underscoring a substantial gender gap in these fields. This disparity is particularly pronounced in regions such as Sub-Saharan Africa, Arab states, and Central Asia [94]. The report emphasises that only 30% of female students in Sub-Saharan Africa pursue STEM fields in higher education. In the United States, women account for only 20% of all bachelor's degrees awarded in computer science and physics, as reported by the National Science Board in 2019 [65]. In Japan, women comprise a significantly small percentage of STEM university graduates, with figures indicating that they make up only about 17.6% of these graduates, according to data from the Ministry of Education, Culture, Sports, Science and Technology in 2020. Similarly, in the European Union, significant gender disparities persist in STEM fields. Women make up only about 16% of ICT graduates, reflecting a broader trend where they constitute approximately 34% of all STEM graduates [24]. These statistics highlight significant gender disparities in STEM fields across these regions. According to Nchimbi [66], the study by the African Development Bank found that only 5% of African women hold careers in STEM fields, compared to 21% of men. This highlights the significant disparity in gender representation in STEM careers in Africa [94]. Meanwhile, a report by the UNESCO Institute for Statistics (UIS) explains that Tanzania has one of the lowest rates of female participation in STEM fields in Africa. For example, in 2019, only 4.4% of the female students in Tanzania were enrolled in STEM-related programs at the university level compared to 21.6% of the male students [94].

Different nations have realised that effective utilisation of the environment by teachers is a catalyst in making learners motivated and interested in learning STEM-related subjects [79]. A conducive learning environment makes learners peacefully socialise and interact in learning, hence developing necessary skills for solving existing problems [87]. Initiatives to improve the learning environment situation for girls' participation in STEM have been made by different nations. The Canadian government has been focusing on improving the experiences of girls and women in STEM for more than 50 years by formulating policies and reforms intended to advance gender equity in the related fields [22]. In China, for example, the Ministry of Education issued several guidelines to promote the importance of STEM education for all. In 2017, technology and engineering were added to the content of the course, which demonstrates the importance of engineering thinking and recognition of STEM education [99]. The US government realised that the competitive nature of the economy in the globalised world depends much on the knowledge and skills gained from STEM, regardless of gender [77]. Thus, the US government advocates STEM for all in policies enacted and practices to eliminate the challenge of girls' under-representation [47].

Similarly, the government of Tanzania has implemented various strategies to address gender disparities and improve the learning environment in STEM education. This is evident in educational policies and practices such as the Development Vision 2025. The vision promotes the provision of science and technology for all by stating that "education systems must cultivate science and technology culture from the lowest levels, giving a high standard of education to all children aged 6-15" [91, p. 20]. Moreover, the government ensures that all learners have access to science education from the early years of schooling. All pupils in primary schools learn the Science subject starting from standard three. Additionally, in secondary schools, all students learn science subjects, including biology, chemistry, physics and mathematics, in form one and form two. In form three, students with ages ranging from 15-17 select subject combinations ranging from art, science and agriculture [67]. Regardless of the efforts, the participation of girls in science subjects is lagging, especially in community secondary schools.

2. Literature review

2.1. Environmental challenges facing girls in STEM

Literature from both developed and developing countries highlights that the underrepresentation of girls in STEM fields stems from a complex interplay of societal stereotypes, gender biases, and educational environments [78, 88]. Sociocultural norms and gendered expectations frequently discourage girls from engaging with science subjects, restricting their educational opportunities and influencing their academic and career trajectories [30, 94]. Additionally, STEM disciplines are frequently perceived as masculine, which leads teachers and parents to underestimate girls' abilities in science from an early age [15, 25]. Negative attitudes toward STEM contribute to girls' low self-confidence and poor self-assessment of their abilities, further exacerbating the underrepresentation in these fields [15, 25]. Meanwhile, educational or class environmental factors are related to school and classroom environment, including poor teaching and learning infrastructure as well as lack of science materials and equipment for teaching science [19]. Additionally, environmental factors such as inadequate school infrastructure, insufficient science materials, and poorly equipped classrooms hinder effective science teaching and learning [19, 40].

The use of inappropriate teaching strategies by teachers has also been identified as a significant factor undermining girls' motivation and engagement in science subjects. A study by Tsakalerou et al. [92] explains that career-related factors also play a crucial role in girls' decisions about pursuing STEM. Many girls question whether STEM professions align with their personal values or offer meaningful societal impact, and some doubt whether these careers are a good personal fit. There is also a gender gap in perceptions of the value and opportunities within STEM, with girls less likely than boys to believe that STEM careers are financially rewarding or socially impactful [93]. A persistent barrier is the lack of female role models and mentors in STEM [92]. Without visible examples of women succeeding in these fields, girls find it harder to imagine themselves in such careers. Female mentors and role models are shown to boost girls' confidence, sense of belonging, and aspirations in STEM, helping to counteract stereotypes and encourage greater participation [2]. Collectively, these barriers contribute to the persistent gender gap in STEM participation [89].

Despite the well-documented gender gap in science and mathematics education in Tanzania, most scholarly attention has centred on higher learning institutions, with researchers like Kinyota [42, 43] and Matete [54] as well as reports from the World Bank Group [80] highlighting persistent disparities in STEM fields at the university level. While numerous studies such as those by Itika et al. [33] as well as Ndalichako and Komba [67] have explored the factors contributing to women's underrepresentation in STEM, ranging from sociocultural norms to psychological barriers, these investigations have largely overlooked the specific environmental challenges that hinder girls' engagement with science and mathematics in community secondary schools. Additionally, although government and policy efforts have aimed to address gender discrimination and improve access, there remains a significant gap in understanding how classroom dynamics, home responsibilities, and the broader learning environment uniquely impact girls at the secondary level. Addressing these gaps is crucial for creating a more inclusive and supportive learning environment that encourages girls to pursue science and mathematics with greater enthusiasm and success. This study was, therefore, necessary to be carried out because its findings are anticipated to contribute significantly to the existing body of knowledge. Thus, the research aims to inform key educational stakeholders about the effective use of the environment for motivating girls to pursue science subjects in community secondary schools [16]. The curriculum development institution and policymakers can leverage the findings of this study to create syllabi that effectively motivate science teachers and promote girls' education. Additionally, the study aims to enhance teaching practices by providing educators with a deeper understanding of the factors contributing to the under-representation of girls in STEM. This knowledge will empower teachers to implement more inclusive and supportive educational approaches, ultimately fostering a more equitable learning environment for all students.

2.2. Effective approaches in promoting girls' participation in STEM

Literature highlights several effective strategies for increasing girls' participation in STEM fields, with a strong emphasis on early exposure and hands-on learning [9, 43, 54]. Interactive activities, such as workshops and real-world problem-solving, are particularly effective in igniting curiosity and fostering sustained interest in STEM subjects [94]. Moreover, creating supportive school cultures that actively combat gender biases and foster inclusive environments where girls feel they belong encourages their pursuit of subjects [10]. Furthermore, ensuring equal access to STEM resources, including labs, technology, internships, and extracurricular activities, supports girls' skill development and practical experience [71]. In addition, mentorship programs connecting girls with female STEM professionals, awareness campaigns challenging stereotypes and community partnerships further empower girls to participate and excel in STEM education and careers. Research by Zachmann [101] and Kinyota [43] emphasises the value of role modelling, noting that exposure to successful female role models can inspire girls to pursue science subjects. Providing girls with access to female STEM professionals as mentors and role models is crucial. Seeing women succeed in STEM careers helps girls envision themselves in similar roles and boosts their confidence and motivation. This is achieved by encouraging accomplished women to actively participate in STEM classes and mentorship programs that can, therefore, play a pivotal role in supporting girls' engagement and persistence in these fields [95].

2.3. Gender disparities in science subjects in secondary schools in Tanzania

The gender gap in science subjects in Tanzania is an important issue, characterised by a significantly lower number of girls compared to boys. Not only are fewer girls participating in these subjects, but they also tend to perform at lower levels than their male counterparts in secondary schools. This disparity is particularly evident in the results of the Certificate of Secondary Education Examinations (SCEE), as illustrated in the table 1.

Table 1 indicates a higher enrollment of girls compared to boys in both years for compulsory subjects such as biology and mathematics. However, the participation and performance of girls in physics and chemistry remain disproportionately lower, suggesting a lack of motivation and the presence of systemic challenges that hinder

Table 1
Number of students in science subjects in O-level between 2021 and 2022 [60–64].

Subject	Year	Candidate sat			Candidate passed					
		Boys	**Girls**	**Total**	**Boys**	**%**	**Girls**	**%**	**Total**	**% of total**
Biology	2018	176922	182380	359302	116624	65.9	100907	55.3	217531	60.5
	2019	201510	220052	421562	125808	62.4	107152	48.7	232960	55.3
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	2020	208792	226628	435420	128421	61.5	111864	49.4	240285	55.2
	2021	231142	256304	487446	199439	73.8	156217	61.3	325656	67.2
	2022	241815	280148	521963	177181	73.5	175885	63.0	353046	67.8
Basic Mathematics	2018	177414	181811	360225	42791	24.1	28912	15.8	71703	19.9
	2019	20189	220473	422332	49864	24.7	34710	15.7	84578	20.0
	2019	20185	220473	422332	49868	24.7	34710	15.7	84578	20.0
	2020	20872	226613	435345	50897	24.4	36685	16.2	87582	20.1
	2021	231044	256321	487365	56438	24.6	38239	15.0	94677	19.5
	2022	241762	280124	521886	60637	25.2	43815	15.7	10448	20.5
Physics	2018	72735	60881	133616	39343	54.1	21111	34.7	60454	45.2
	2019	69877	58567	128444	39746	56.9	22396	38.2	62141	48.4
	2019	69877	58567	128444	39746	56.9	22396	38.2	62141	48.4
	2020	66365	53977	120342	37759	56.9	21049	39.06	58808	48.9
	2021	65162	51448	116610	44096	63.5	23000	45.0	64096	55.3
	2022	63044	51428	1114472	47062	74.8	30947	60.4	78009	68.3
Chemistry	2018	87973	77803	165776	60178	68.4	42286	54.4	102464	61.8
	2019	86116	76661	162777	70168	81.5	54784	71.5	124952	76.8
	2019	86116	76661	162777	70168	81.5	54784	71.5	124952	76.8
	2020	82626	71517	154143	74290	83.9	59989	83.91	134249	87.1
	2021	82228	69877	152105	77108	94.3	61946	89.3	139054	92.0
	2022	82445	72992	155437	78315	95.2	66900	91.9	145215	93.7

their engagement in these subjects. Furthermore, it is notable that girls generally perform lower in biology and mathematics, subjects that are compulsory for all students, compared to their male counterparts. This trend highlights a significant gap in girls' motivation towards science, as evidenced by their lower participation and performance levels. The trend highlights an urgent need for targeted interventions to boost female participation and performance in science disciplines, particularly in countries like Tanzania, which has one of the lowest rates of female participation in STEM fields globally. Thus, addressing this issue is crucial for fostering a more equitable and inclusive environment in STEM, particularly in light of the rapidly growing population of women [77].

The participation of girls in STEM subjects can, therefore, be improved by motivating them to develop positive attitudes towards science subjects [86, 96]. This can be achieved only if they can be provided with a conducive learning environment that makes them comfortable, confident, and motivated to learn [37, 75]. According to Kerenge [37] and Rachmatullah et al. [75], creating such an environment allows students to thrive academically and personally. Thus, when learners feel at ease and supported, they are more likely to engage actively in their education, leading to improved outcomes and a deeper commitment to their learning journey.

Researchers anticipated that addressing the issue of underrepresentation of girls in STEM at lower educational levels would prevent its impact from being felt at higher levels and in future careers in related fields. The failure to address the challenges faced by girls in science subjects significantly limits their access to STEM education and career opportunities, thereby marginalising them and contravening human rights and equality initiatives globally [1]. Besides, the United Nations in 2015 agreed to attain the Sustainable Development Agenda by 2030 by all member states. For instance, goal number four of the Sustainable Development Goals (SDGs) emphasises inclusive and equitable quality education and promoting lifelong learning for all [95]. Moreover, goal number five also insists on achieving gender equality and empowering all women and girls by ending all forms of discrimination against all women and girls everywhere. Increasing girls' participation in STEM subjects is a crucial strategy for empowering them and combating discrimination. Therefore, this is the reason for conducting the study related to the environmental factors influencing girls' participation in science education in secondary schools in Tanzania. Therefore, this study aimed to explore how teachers use their teaching and learning environment to draw more girls into science-based subjects. The following objectives guided the study:

1. To examine the environmental challenges that affect girls' participation in science and mathematics subjects.
2. To explore how teachers utilise the environment to enhance girls' participation in science and mathematics subjects.

3. Theoretical framework

The study was guided by Albert Bandura's social cognitive theory, which posits that human functioning arises from a reciprocal interaction among personal influences, environmental contexts, and behavioural characteristics [5]. This theory serves as a foundation for the development of constructivism and cooperative learning, both of which are pivotal in contemporary science education [97]. At the core of social cognitive theory is the concept of triadic reciprocal determinism, which illustrates how personal factors, environmental contexts, and behavioural patterns continuously interact with and influence one another in a bidirectional relationship [57].

Reciprocal determinism, as proposed by Albert Bandura, enhances learning outcomes by emphasising the continuous and dynamic interplay between personal factors, environmental influences, and behavioural components. Personal factors include beliefs, self-efficacy, emotions, cognition, affect, and biological events. At the same time, environmental determinants encompass social contexts, physical settings, and the influence of others, such as societal norms and access to resources [82]. Behavioural components refer to the skills, practices, and actions individuals develop and employ as they interact with their surroundings. This model highlights that behaviour is not shaped in a linear, one-way manner; instead, each factor, personal, environmental, and behavioural, mutually influences and is influenced by the others in a constant feedback loop. As a result, changes in any one of these domains can lead to adaptive shifts in the others, supporting ongoing learning and growth. This reciprocal process means individuals are active agents in their development, shaping and being shaped by their environment and actions, which ultimately fosters more effective and adaptive learning outcomes.

A central tenet of this theory is the concept of perceived self-efficacy, which plays a crucial role in fostering girls' confidence and belief in their own capabilities [6, 7]. Self-efficacy, as defined by Bandura, encompasses beliefs regarding one's ability to learn or perform tasks at designated levels. This belief system is essential for motivating girls to engage with challenges and persist in their efforts [35]. The reciprocal interaction between personal factors, environmental factors, and behavioural characteristics in the process of learning is illustrated in the figure 1.

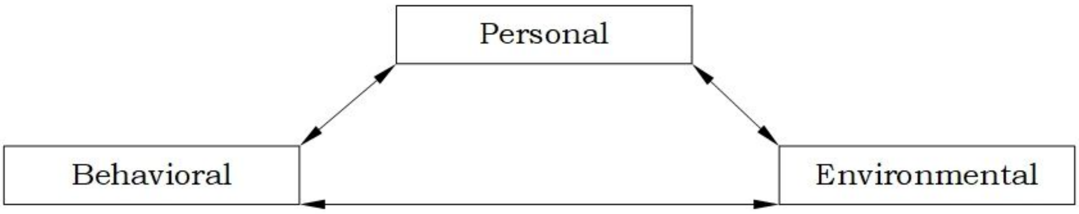

Figure 1: Social cognitive theory [82].

This model positions humans as both products and producers of their environment. Through this reciprocal interaction, individuals actively construct their understanding of the world rather than passively absorbing information.

3.1. Applicability of the theory to the study

The theory helps teachers to effectively design learning environments that leverage the power of reciprocal determinism, the dynamic interplay between personal factors, behaviours, and environmental influences to enhance girls' learning outcomes [83]. Teachers may use the environment to improve learning by making girls understand abstract facts from the real environment [98]. This involves designing activities with carefully regulated levels of challenge, enabling students to achieve incremental successes that steadily build their confidence through tangible accomplishment. Furthermore, structuring physical or virtual spaces to promote peer interaction, such as through cooperative learning groups, reciprocal teaching pairs, or collaborative projects, allows students to observe and model effective strategies, benefit from diverse perspectives, and engage in shared problem-solving. By scaffolding these peer activities with explicit instruction, guided practice, and structured reflection, teachers empower students to take increasing responsibility for their learning, fostering both self-efficacy and collective efficacy within the learning community.

To maximise the benefits of reciprocal determinism in the classroom, teachers may create a learning environment that fosters students' belief in their capabilities by designing learning activities with appropriate levels of challenge that allow students to experience incremental success, thus building confidence through accomplishment by offering specific, timely feedback that acknowledges progress and suggests concrete steps for improvement, reinforcing the connection between effort and achievement. Additionally, the theory emphasises the importance of teachers serving as exemplary role models, demonstrating acceptable character and moral conduct while also inspiring success among girls in STEM fields [82]. By embodying these values and demonstrating success, teachers can influence students' perceptions of their own abilities and potential. In summary, this educational framework not only enhances understanding through environmental engagement but also cultivates self-efficacy and provides positive role models, thereby contributing to a more effective learning environment.

4. Research methodology

4.1. Research approach and design

The study adopted a qualitative approach to deeply explore human perceptions and interpretations of facts, behaviours, and events as shaped by lived experiences in their natural settings, aligning with Yin [100] emphasis on the importance of context in qualitative research. Employing a multiple-case study design enabled a comprehensive and nuanced examination of the phenomenon across varied environments, as recommended by Creswell and Creswell [17]. This approach is particularly valuable because it allows for the analysis of similarities and differences across cases, thereby enhancing the depth and credibility of findings. By selecting schools with contrasting academic performance, two with strong results and two with weaker outcomes in the 2022 Certificate of Secondary Education Examinations, the study was able to capture a broad spectrum of contextual influences and educational dynamics. Analysing multiple cases in this manner not only facilitates a richer understanding of the factors affecting academic achievement but also supports more robust and transferable insights, as each case is considered both individually and collectively within its unique context [16].

4.2. Sample and sampling procedures

According to the Mbeya Educational Officer, in 2023, the Mbeya Region had 203 government secondary schools. The region had 145,876 students, 68,681 of whom were boys and 77,195 were girls. The number of teachers in those schools was 4,907. Among them, 1,494 were science teachers. To select research participants, a purposive sampling procedure was employed, ensuring that individuals with relevant insights were included in the study [100]. Thus, four community secondary schools in the Mbeya Region were purposefully selected for this study, with two exhibiting strong academic performance and the other two demonstrating weaker results in the 2022 Certificate of Secondary Education Examinations (CSEE). This selection aimed to provide contrasting perspectives on the factors influencing girls' performance in science subjects within community secondary schools. The emphasis on academic performance is critical, as it serves as a key indicator of student motivation throughout the learning process [77]. A total of 40 participants were purposively selected for the study, comprising 16 science teachers and 24 students. Specifically, four teachers from each of the participating schools were included, along with six students from each school, all of whom were in form three and enrolled in science majors. This particular class was chosen because it is at this stage that students typically make decisions regarding their subject combinations, as noted by Ndalichako and Komba [67].

4.3. Location of the study

The Mbeya Region was selected for this study due to its high secondary school enrolment rates, which reveal significant gender disparities in science performance [39]. The focus on community secondary schools is particularly relevant, as these institutions were established to fulfil the objectives of Education for All, a commitment made during the Dakar Framework for Action in 2000 [90]. This framework aimed to reaffirm the vision set forth in the World Declaration on Education for All, adopted in 1990 [70]. Notably, enrolment rates in community secondary schools surpass those of other public secondary schools that typically attract students with higher academic performance [3]. This context underscores the need to explore the factors contributing to gender disparities in educational outcomes within these schools.

4.4. Methods of data collection

The study employed different methods of data collection, including the classroom observation method, which is the most reliable tool for data collection in gathering firsthand field information as the participants engage in actions and experiences in their natural settings [27, 73]. This approach enabled researchers to gather in-depth insights into the views, experiences, and feelings of participants regarding how the teaching environment influenced girls' participation in learning [45]. Four observations were possible for each school, meaning that each form three science teachers was observed. This method was also helpful in collecting information that could not be obtained through other tools. Therefore, non-participatory observation allowed the researchers to observe teachers' practices without direct involvement. In this study, semi-structured interviews and focus group discussions (FGDs) served as the primary methods of data collection. The researchers prepared interview guides that comprised open-ended questions. According to Cohen, Manion and Morrison [14], open-ended questions provide researchers with room to probe more into the answers in order to collect detailed information. Kivunja and Kuyini [45] point out that, unlike other data collection tools, interviews enable researchers to collect in-depth data from respondents. In addition, Patton [72] observes that interviews are helpful in generating rich qualitative data due to their flexibility, focus and time effectiveness.

Researchers organised interviews in natural settings in schools without disrupting school timetables and ongoing classes. Gunawan [29] points out that interviews should not take a long time to avoid boredom. Thus, all interview sessions in this study lasted between 45 minutes and one hour. FGDs were conducted with students to fill in any gaps identified during the observation and interview phases, ensuring a comprehensive understanding of the environmental factors affecting girls' science educational engagement. During FGDs, participants had time to share experiences, ideas and expressions of beliefs, meanings and values to arrive at a collective understanding of their perspectives the utilisation of the environment in making girls participate in learning science and mathematics. The details from both interview responses and FGDs were noted down and organised before a thorough analysis was done. Creswell and Creswell [17] notes that field data should be subjected to a comprehensive, in-depth examination to remove all kinds of nuances that might destabilise the results.

Additionally, documentary reviews played a crucial role in collecting data across various themes and sub-themes aligned with the study's objectives. The documents analysed included educational and training policies, teachers' schemes of work, lesson plans, and syllabi for science and mathematics subjects. These documents were examined to identify guidelines for teachers on how to effectively use learning environments to enhance girls' participation in education. The data collected from the field were then subjected to rigorous critical analysis to ensure the validity of the findings.

4.5. Data analysis

The data were analysed immediately following collection, aligning with the perspectives of other researchers who emphasise that timely data analysis is essential [14, 31]. This approach is critical as it enhances the relevance and accuracy of the findings. The researchers employed the six stages of data analysis proposed by Braun and Clarke [8] as explained by Dawadi [18], which facilitate a systematic examination of qualitative data. The stages include data familiarisation, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing a research report. All transcripts and audio recordings were organised and coded to fit the study's purpose. The analysis for developing the story was grounded in themes derived from the research objectives, ensuring minimal overlap between them. During familiarisation, the researchers were immersed in the data to be familiar with it through repeatedly listening to the recordings, reading, rereading, and summarising the content so as to understand and get the interesting meaning that is provided across the data set in relation to research objectives. The researchers compiled the data by using different files according to their category, i.e., interviews, focus group discussions, observation, and documentary review.

In the second phase, the researchers engaged in identifying specific segments of content that are relevant to the study. This was done by highlighting and labelling phrases of words to the most repeated and interesting words that appeared to be relevant to the study. The coding process dealt with the entire dataset systematically and thoroughly. The third phase of analysis involved generating initial themes: These are central concepts that were developed from codes developed in the second phase. The researcher identified shared patterns of meaning across the dataset and compiled the clusters of codes that seemed to share a core idea, which provided a meaningful answer to the research objectives [31]. Themes were broader than codes, and they are units of analysis which are helpful in the interpretation of the data. The fourth phase of data analysis involved reviewing themes. It involved the researcher verifying the themes to establish whether they make sense in accordance with patterns of shared meanings in relation to research questions in the dataset. Drawing and verifying conclusions were attained from the emergent themes inferred from the findings according to the research objectives and the research questions. The fifth phase involved refining, defining and naming themes. During this phase, the researcher fine-tuned the analysis, ensuring that each theme was clearly demarcated and was built around a strong core concept based on the data [38]. The sixth and final phase involved summarisation (writing up). It dealt with producing the report of the findings.

4.6. Trustworthiness of the research

Lincoln and Guba [49, 50] proposed four essential criteria for evaluating the trustworthiness of qualitative research, namely credibility, transferability, dependability and confirmability. Thus, in order to meet the objectives of the study and ensure that the study findings are trustworthy, those four criteria were adhered to.

4.6.1. Credibility

To ensure the trustworthiness and congruence of the research findings with reality, the researcher implemented several rigorous strategies. Primarily, methodological triangulation was used to enhance credibility, involving the integration of multiple data collection methods such as observation, interviews, focus group discussions, and documentary review. This approach allowed for the cross-verification of data from diverse sources, thereby minimising biases and increasing the reliability of the results [85].

4.6.2. Transferability

To establish the applicability of the study, transferability, the extent to which research findings can be applied to other contexts, was carefully considered [21]. Transferability in qualitative research is achieved by providing thick descriptions: rich, detailed accounts of the research context, participants, and processes, which allow others to determine whether the findings are relevant to their own setting. In this study, the researchers ensured transferability by generating comprehensive data and offering detailed descriptions of the circumstances and context [21]. Such thick description enables readers and future researchers to judge the potential for applying the findings to other situations, especially when local constituents find the portrayal sufficiently rich for their own use. Additionally, the careful selection of both the sample and the study area was undertaken to enhance the likelihood that the findings would be meaningful and applicable in other contexts, thus supporting broader relevance beyond the immediate research setting.

4.6.3. Dependability

Dependability, as articulated by Lincoln and Guba [50], is a cornerstone of trustworthiness in qualitative research, focusing on the consistency and reliability of findings across the research process. It addresses whether the research procedures are logical, traceable, and thoroughly documented, thereby ensuring that if the study were replicated under similar conditions, comparable results would be obtained [49]. In this study, dependability was established through the use of audit trails, which provided detailed accounts of data sources, collection methods, and analytic techniques, thus demonstrating the legitimacy and transparency of the findings. Additionally, prolonged engagement with participants and comprehensive reporting of data contributed to dependability, as these practices allow for a deeper understanding of the context and phenomena under investigation [85]. Such rigour ensures that other researchers, when repeating the study under similar circumstances, would likely arrive at similar conclusions, thereby reinforcing the study's reliability and trustworthiness.

4.6.4. Confirmability

Confirmability in this study was ensured through multiple strategies. The use of triangulation in data collection helped to reduce researcher bias by incorporating diverse sources and methods [31]. Additionally, member checking was conducted after data collection, allowing informants to review the recorded information to verify that it accurately reflected their statements. Furthermore, frequent debriefing sessions with supervisors were held to draw on their expertise and address any credibility concerns, thereby enhancing the overall trustworthiness of the findings.

4.7. Ethical considerations

Ethical considerations for this study were paramount. First, the researchers sought a permit from the University of Dodoma (UDOM), whereby a clearance letter was given, and a permit or introductory letter was obtained from the office of the Vice Chancellor. In this way, the letter introduced the researchers to the Regional Administrative Secretary of the Mbeya Region, securing research clearance from the University of Dodoma. The researchers also secured a permit from the Mbeya Regional Administrative Secretary as well as the District Administrative Secretary to conduct the study in four different schools. The researchers also ensured that participation in this study was entirely voluntary, aligning with ethical standards that prioritise participant autonomy. Participants were thoroughly informed about the study's nature and purpose, which is essential for obtaining informed consent, as emphasised by Silverman [84] and Gunawan [29]. Furthermore, confidentiality was rigorously maintained to safeguard participants' identities, reinforcing and granting anonymity before they were invited to participate in interviews and FGDs [17].

5. Findings

The following section presents the study's findings, which are based on the themes extracted from field data and guided by the research objectives.

5.1. Environmental challenges affecting girls' participation in science

This study reveals that learning science subjects poses a significant challenge for girls, primarily due to environmental barriers that hinder their participation. These obstacles create a complex landscape for girls to engage effectively with science education, limiting their opportunities and potential in these fields. Table 2 demonstrates the challenges that girls face in STEM.

Table 2 highlights the key challenges affecting girls' participation in science, based on a total of 40 responses. The most significant barriers identified are stereotypes and cultural norms, as well as a lack of role models, each accounting for 22.5% of the challenges. Poor infrastructure follows closely, representing 20% of the issues faced. Inadequate teaching facilities contribute to 17.5% of the challenges, while gender-biased curricula account for 10%. Lastly, a lack of support from society is noted as a challenge by 7.5% of respondents. These findings underscore the multifaceted nature of obstacles that girls encounter in pursuing science, ranging from societal attitudes and representation to physical and educational resources.

Table 2
Challenges affecting girls' participation in science.

Challenges facing girls in STEM	*N*	%
Stereotype and cultural norms	9	22.5
Lack of role models	9	22.5
Poor infrastructure	8	20.0
Inadequate teaching facilities	7	17.5
Gender biased curricular	4	10.0
Lack of support from society	3	7.5
Total	**40**	**100.00**

5.2. Specific challenges facing girls in learning science subjects

5.2.1. Stereotype and cultural norms

Societal perceptions often depict STEM fields as male-dominated, discouraging girls from pursuing these subjects. Studies have shown that such stereotypes are internalised early in childhood, shaping girls' self-concept and interest in STEM [12]. As a result, they create the degree to which a stereotype is created that women are better at the arts and men are better at science- and mathematics-based subjects [30]. Consequently, such ideas lead to poor parents, peers and teachers' support for girls to pursue STEM-related subjects [25, 30]. A girl from school C said:

> Another significant challenge is the prevalence of misguided beliefs, particularly in the context of gender roles. For instance, if someone is informed that a girl is pursuing science, they might express disbelief. Such scepticism often stems from outdated notions that girls are primarily expected to stay at home, manage household chores, prepare meals for their families, and eventually get married. (FGD C, Pos. 10)

A girl, C:3, from school D also explained:

> I have experienced firsthand comments that questioned my ability to succeed in science, based on the assumption that if my brothers couldn't manage it, then I certainly couldn't. This discouragement can be deeply personal and has been particularly damaging. These experiences highlight the broader societal challenges that impede girls' education and reinforce gender stereotypes, creating a significant barrier to their academic and professional aspirations. (FGD D, Pos. 3)

These stereotypes create a discouraging environment, leading talented individuals to shy away from subjects where they could excel. Society often associates science subjects with masculine attributes, leading to the perception that they are inherently more difficult for girls. This stereotype creates barriers for female students, prompting teachers to adopt various strategies to encourage their participation and challenge these misconceptions. A study by Kira and Komba [44] found that cultural beliefs and social norms limit women's educational opportunities.

5.2.2. Lack of role models

The study found that the absence of visible female role models in STEM perpetuates the belief that women do not belong in these fields. Girls are not exposed to women who succeed in related fields so as to be inspired by their success stories.

> The absence of role models in society is a challenge for girls in pursuing these subjects. It is particularly important to showcase role models illustrating that women can excel in science and mathematics subjects, which can help to overcome some of the social and cultural norms that prevent women from pursuing STEM disciplines and careers in the future. (Biology teacher, School D, Interviewee 18, July 26, 2023, Mbeya)

Female role models in STEM can inspire young girls by demonstrating that women can excel in these fields. This visibility boosts girls' confidence in their STEM abilities and encourages them to pursue careers in science and engineering. In support of the findings of this study, a study by Prebreza et al. [74] also identified a lack of role models, limited access to STEM resources, and gender stereotypes as the major barriers to female students' participation in STEM fields.

5.2.3. Gender-biased curricula and teaching practices

The documents guiding teachers failed to provide clear guidance on how teachers can effectively use the environment to motivate girls in learning. As a result, teachers had to rely on their own creativity to develop strategies. Researchers noted that the documents lacked specific clarifications on methods to enhance girls' motivation in the learning process. This absence of detailed guidance meant that teachers were left to innovate and experiment independently, which could lead to inconsistent outcomes.

5.2.4. Girls' lack of support from society

The causes of gender gap in science and mathematics are also caused by a lack of support from families and communities due to gender stereotyping. Explaining this, a Biology teacher from school C said:

> It is crucial to shift the mindsets of parents to recognise that female students also have the right to pursue science subjects. If we fail to do so, there will be contradictions between our efforts at school and the discouragement they face at home. At school, we work to instil the belief in girls that science is accessible to everyone, but when students return home, they often encounter parental discouragement. This inconsistency can undermine our efforts and hinder the progress of female students in science. Therefore, engaging parents and changing their perceptions is essential to create a supportive environment that encourages girls to pursue science without facing obstacles. (Biology teacher, School C, Interview 12, July 18, 2023, Mbeya)

The lack of cooperative support from teachers and parents can often act as a significant barrier to girls' efforts to learn science and mathematics. While teachers at school may make concerted efforts to encourage girls in their academic pursuits, the situation often changes when they return home. At home, the support and encouragement that girls receive may be limited, creating a challenging environment that undermines their efforts to excel in these subjects.

A student C:1 from school D said:

> Achieving one's dreams can be significantly hindered by the living conditions at home. For instance, if a person faces poor living conditions, they may struggle to pursue their interests in science due to the numerous requirements, such as exercise books, graph papers, and textbooks. This challenge becomes even more daunting when considering home economics, as the financial strain can lead to feelings of desperation. The combination

> of these factors can make it difficult for individuals to stay motivated and focused on their goals, ultimately affecting their ability to succeed. (FGD E, Pos. 14)

A study by Fernández García et al. [26] found that the low self-efficacy of female students and the lack of support from family and peers were major obstacles to their participation in STEM programs. Similarly, a study by Sanga et al. [81] identified a lack of support and encouragement from family, peers, and teachers, as well as limited access to funding and scholarships, as significant challenges facing female students in STEM fields in STEM fields in Tanzania.

5.3. Other challenges facing girls in learning science subjects

5.3.1. Poor infrastructure for effective teaching

The researchers observed that there are other environmental challenges that both girls and boys face when effectively engaging with science subjects. In particular, the conditions in schools A and B were noted to be problematic due to poor learning infrastructure, which hampers students' ability to study science effectively. At school A, the Physics teacher highlighted these difficulties, emphasising how inadequate facilities and resources negatively impact students' learning experiences and outcomes in science education.

> Motivating girls to learn science subjects is challenging due to an unfavourable environment that hinders their academic progress. The laboratories used for science lessons were originally designed as classrooms, limiting their functionality for practical experiments. These infrastructural shortcomings accelerate the broader issue of gender disparity in science education, as girls face compounded challenges, including socio-cultural biases and inadequate resources that discourage their participation in STEM fields. (Physics teacher, School A, Interview 2, July 21, 2023, Mbeya)

During data collection, it was evident that poor infrastructure was a challenge facing girls as they participated in science subjects. The researchers observed some teachers in schools A and B sitting outside in the sun due to cold weather, especially during early morning periods.

5.3.2. Inadequacy of teaching facilities

The study highlights critical challenges faced by community schools, particularly the severe scarcity of teaching facilities, which negatively impact both teachers and students, especially girls learning science subjects. Respondents emphasised that inadequate resources, such as insufficient science textbooks, hinder effective teaching methods. One respondent from school D noted this issue during interviews, underscoring the need for better infrastructure and resources to support science education.

> We experience challenges during teaching due to the scarcity of textbooks. Textbooks are generally insufficient. (Academic master, School D, Interview 14, July 26, 2023, Mbeya)

According to the respondents, it was not easy for science teachers to motivate girls to learn science in such a situation. Lack of enough resources caused learner to share the few resources available such as books. It was hard for teachers to effectively engage all learners in learning activities with few resources. This scarcity of resources often led to a scarcity mind-set among teachers, which in turn, impaired their cognitive and behavioral effectiveness in teaching. As a result, the problem was further exacerbated, creating additional barriers to effective science education for girls.

5.3.3. The impact of poor school infrastructure on girls' participation in science subjects

The study revealed that poor learning infrastructure significantly hindered girls' ability to learn science subjects. This situation contributed to increased absenteeism, diminished confidence, and low morale, which negatively affected their participation. Additionally, the schools faced inadequate water supply and poor sanitation facilities, disproportionately impacting female students. These challenges led to irregular attendance and a higher dropout rate among girls. During interviews in school A, one respondent made the following remark:

> The infrastructural shortcomings not only hinder girls' participation and engagement in science but also contribute to absenteeism and a general lack of motivation to pursue the science subject. The school lacks adequate water, proper toilets, and well-equipped laboratories, which negatively impacts girls' learning experiences, particularly during menstruation. Insufficient water and poor sanitation facilities make it difficult for girls to manage menstrual hygiene effectively, leading to absenteeism during their menstrual cycles. (Physics teacher, School A, Interview 2, July 21, 2023, Mbeya)

A girl from school B also explained the following during a focus group discussion:

> Poor learning infrastructure is among the challenges that we face when learning science subjects; for example, the laboratories in our school are not supportive enough to make us attracted to learn accordingly. (FGD B, Pos. 13)

Improving these basic facilities is essential to create a more supportive environment that encourages girls to attend school regularly and participate fully in science education.

5.4. Teachers utilising environment in enhancing girls' learning of science

The study revealed that teachers effectively used physical, cognitive, and social elements of the environment to encourage girls to learn science and mathematics. To achieve this, teachers implemented various strategies aimed at actively involving girls in related fields. Table 3 demonstrates the strategies that teachers use to utilize the environment for girls' learning.

Table 3
Utilising the environment for girls' science learning.

Teachers utilizing environment	***N***	**%**
Advising girls to learn	12	30.0
Providing girls with opportunities to learn	9	19.5
Creating friendly learning environment	8	18.5
Building confidence to girls	6	16.5
Using motivators	5	15.5
Total	**40**	**100.00**

Table 3 illustrates how teachers utilise the environment to support girls' learning, as reported by 40 participants. The findings reveal that the most common strategy, mentioned by 30% of respondents, is advising girls to learn, highlighting the importance of direct encouragement and guidance. Following this, 19.5% of participants noted that teachers provide girls with opportunities to learn, suggesting that access and exposure to learning activities are key components. Creating a friendly learning environment was identified by 18.5% of the participants, emphasising the role of a supportive and welcoming classroom atmosphere. Additionally, 16.5% of respondents highlighted that teachers focus on building girls' confidence, which is crucial for their academic engagement and success. Lastly, 15.5% of the participants pointed out the use of motivators by teachers to inspire and sustain girls' interest in learning. Overall, these findings illustrate a multifaceted approach by teachers to foster girls' education through encouragement, opportunity, supportive environments, confidence-building, and motivation.

5.4.1. Advising girls to participate in science and mathematics for future careers in STEM

The study highlights the pivotal role that science teachers play in advising students, especially girls, which significantly enhances their participation, engagement, and persistence in science subjects. This personalised guidance occurs through various interactions, one-on-one conversations, classroom teaching moments, and dedicated meetings, providing multiple opportunities for meaningful dialogue. Advice is particularly crucial when students encounter difficult academic decisions, such as choosing between science and art-based subjects. At these junctures, clear, informed, and empathetic advice helps students weigh their options realistically, understand the implications of their choices, and align their decisions with their interests and future goals. Without such support, students may feel uncertain or discouraged, potentially leading to disengagement or premature withdrawal from science pathways. In this regard, a Mathematics teacher from school B said:

> As soon as I began teaching Form One students, I emphasised to girls that they should not fear any subject, particularly mathematics. I explained to them that mathematics is just as normal as any other subject and that mastering it can enhance their understanding of various topics of other subjects. I told them that the beauty of mathematics lies in its foundational concepts; by grasping a few key principles, students could significantly improve their performance. This is in contrast to other subjects that often require extensive memorisation of notes. Once students understood these basic concepts, they tended to appreciate the subject more, leading to a greater likelihood of developing a love for mathematics and achieving better results. (Mathematics teacher, School B, Interviewee 10, July 20, 2023, Mbeya)

This narration illustrates how teachers proactively advised learners, particularly girls, from the outset of their education. They aimed at fostering a sense of ease and motivation in subjects like science and mathematics. Thus, to achieve this, teachers employed various strategies to inspire girls and cultivate their interest in these fields. In addition to one-on-one conversations, they organised meetings where multiple teachers engaged with students by telling them about the importance and benefits of pursuing these subjects. Encouraging students, particularly girls, to pursue science subjects significantly enhanced their career prospects. As a Physics teacher from school A explained that:

> I tell learners, especially girls, that a background in science is likely to guarantee employment opportunities. The knowledge and skills acquired through science education not only prepare students for white scholar jobs but also open avenues for self-employment. This perspective fosters motivation among students to engage with science subjects more deeply. (Physics teacher, School A, Interviewee 5, July 17, 2023, Mbeya)

The supportive environment fostered by teachers encouraged girls to persist in their studies. Beyond decision-making, effective advice fosters a nurturing environment where students feel valued and understood. When teachers actively listen and respond to students' concerns, they build trust and confidence, which are essential for motivation and resilience. This supportive atmosphere encourages students to persist through challenges, take intellectual risks, and remain committed to their studies. Research has confirmed that the advice provided by teachers significantly enhanced girls' understanding of the potential of science and mathematics for their future careers. This guidance is particularly crucial as it addresses the underrepresentation of girls in STEM, leading to an increase in female participation in science education, especially in schools "C" and "D". For girls in particular, who often face societal stereotypes and lower expectations in STEM fields, targeted advice from teachers can counteract these barriers. Encouragement and tailored guidance help to boost girls' self-efficacy and interest in science, promoting gender equity in academic participation and future career choices.

5.4.2. Providing opportunities for girls to learn science

The study revealed that girls actively engaged in learning science subjects through various strategies, including participation in hands-on afterschool programs, interaction with female role models, and opportunities for practical learning experiences. Consequently, when selecting students for science subjects, priority was given to those who performed well, achieving grades A, B, and C in related subjects, to encourage their enrollment in science-focused fields. However, in some cases, girls were given preferential consideration during student selection and instruction, even when their academic performance did not fully meet the established criteria. This practice underscores the importance of adopting a balanced approach that supports all students while also addressing underlying biases related to gender and perceptions of academic ability in science subjects. As one teacher from school A noted, these efforts aim to both encourage girls' participation and maintain academic standards.

> In instances where some girls do not meet the required entry points for pursuing science subjects, we actively seek their opinions on whether they would be interested in joining science classes. For those who express willingness, we provide a three-month observation period to assess their capabilities in subjects like chemistry. This approach allows us to evaluate their potential and readiness to continue with the science curriculum effectively. The initiative aims to encourage participation among girls who may otherwise feel discouraged by societal stereotypes or academic pressures, thus fostering a more inclusive environment for science education in schools, particularly. (Chemistry teacher, School A, Interviewee 5, July 17, 2023, Mbeya)

In this same vein, the Physics teacher of school C said:

> We identified a group of students, particularly girls, who demonstrated potential in studying science but had not performed well in examinations. Thus, to support their improvement, we implemented an intensive intervention strategy that included additional study sessions. We encouraged these students to dedicate extra time for self-study and provided structured teaching early in the morning and during evening sessions from 3 PM to 5 PM. This approach aimed to enhance their understanding and motivation in science and mathematics, particularly in physics, fostering a more engaging learning environment. Our goal was to instil a sense of confidence and

> encourage persistence in their academic pursuits, ultimately helping them achieve better results in their examinations. (Physics teacher, School C, Interviewee 2, July 21, 2023, Mbeya)

The previous narrations indicated that those students who showed interest in joining those particular subjects, especially girls, were given a chance to study with special care. Moreover, it was found that, during the teaching and learning process, girls were more engaged in the process than boys, and this really helped them. Teachers provided tasks in groups and appointed girls as leaders of those groups, thus making them work close to teachers and become confident. They were assured assistance whenever they found those tasks to be tough. This is done not as a way of discriminating against boys but rather in order to help girls since they are perceived to be shyer as compared to boys. These were explained by a Mathematics teacher of form four from school A, as he said:

> I assign leadership roles to girls during group discussions. I also tell them that if they find a topic that is tougher, to better consult me for help. I make sure to teach that topic instead of letting them mislead others. This results in their confidence, and you may find that when they face a challenging problem before they go to class, they consult me. Every Friday, we meet so that we get a chance to know if there were any problems concerning the tasks that I gave them. (Mathematics teacher, School A, Interview 4, July 31, 2023, Mbeya)

Similarly, a Chemistry teacher from school D also explained how he availed opportunities to girls for learning his subject by saying:

> I usually arrange groups of students, and in those groups, I try to mix boys and girls. I make sure that in those groups, there are more girls, and even during presentations, I like them to participate more than boys in order to make them active. This is because sometimes girls fear participating. Thus, if you make them group leaders, they become active. (Chemistry teacher, School D, Interview 16, July 26, 2023, Mbeya)

Based on their explanations, teachers found their teaching role started from streaming the students, preparing for teaching, and evaluating learners' learning processes.

5.4.3. Teachers create a friendly learning environment for girls in science

The study found that most girls tend to shy away while learning science subjects as compared to boys. Moreover, they perceive themselves to be weaker than boys and also tend to believe that science fields are meant for boys and not for them [25]. In that case, teachers create a friendly learning environment for them so as to make them actively engaged in the learning process by designing lessons that relate science concepts to real-world issues or students' everyday experiences, especially those relevant to girls' interests and cultures. For example, the use of examples from health, environmental issues, or technology that impact their communities. By encouraging students to share their own experiences and connect them to scientific ideas, making learning more meaningful and inclusive. Additionally, by encouraging girls to share their own experiences and connect them to scientific ideas makes learning more meaningful and inclusive. Commenting on this issue, the Biology teacher from school D explained the following:

> We planted a variety of vegetables, including pumpkins, which provided a wonderful learning experience for the students. They were able to observe

> firsthand examples how pumpkin leaves spread out and grow, gaining a deeper understanding of plant development. Some of the girls even took part in planting the pumpkins themselves, which made the experience more engaging and hands-on. After nurturing the plants and watching them grow, we successfully harvested some of the pumpkins. The excitement was deep among the students. They were thrilled not only to see the fruits of their labour but also to enjoy the food they helped cultivate. At the same time, we incorporated lessons on plant movements, allowing the students to observe how plants respond to their environment. (Biology teacher, School D, Interview 18, July 26, 2023, Mbeya)

This activity was particularly important for girls because it connected learning to real-world environments. For girls to actively participate in science subjects, it is essential that they feel comfortable and supported while at school. Thus, a peaceful and welcoming atmosphere plays a crucial role in encouraging girls' engagement in science learning, highlighting the need for a safe and nurturing environment where they can thrive academically. As such, teachers ought to make sure that girls feel that they are safe and cared for. A Biology teacher from school D added the following remarks:

> There was a case of one student who had no parents and was raised by certain good Samaritans whom she met at church. Even though she got support from that family, she still experienced some challenges in her life and studies. I found that financial problems were among the challenges that she encountered. I assured her of my support, and I am happy to inform you that she was able to finish her studies well. (Biology teacher, School D, Interviewee 18, July 26, 2023, Mbeya)

The explanations above reveal that teachers care not only for girls' education but also their well-being while at school. Thus, they make students feel loved, comfortable, and confident about learning.

5.4.4. Teachers build girls' confidence to participate in science

The study revealed that teachers help girls to reverse their negative attitude towards studying science subjects by helping them to build confidence in learning science. This was done through the use of different techniques, such as ensuring girls are regularly assigned various roles in group experiments, such as lead investigator, equipment handler, or presenter, and rotating these roles so every student gains diverse experiences. This approach prevents boys from dominating hands-on tasks and ensures girls develop a broad set of scientific skills, increasing their confidence in practical and leadership abilities. Moreover, engaging them in tangible, practical assignments in laboratories helps clarify the science, making it more accessible and relevant. Research shows that hands-on activities, especially those tied to daily life, significantly boost girls' motivation and confidence in learning science. A Biology teacher from school C had the following to say:

> Many girls experience an inferiority complex, which often manifests as a reluctance to participate in classroom discussions. This phenomenon is particularly evident when girls hesitate to answer questions unless explicitly called upon by teachers. Teachers play a crucial role in addressing these issues by providing encouragement and acknowledging efforts through praise and minimal verbal support. This approach not only helps to boost the girls' confidence but also fosters a more inclusive classroom environment

> where they feel valued and empowered to engage actively in their learning process. (Biology teacher, School C, Interview 12, July 18, 2023, Mbeya)

Another teacher from school D also said.

> In my role as a chemistry teacher, I prioritise creating an inclusive environment during group work by intentionally mixing boys and girls, ensuring that there are more girls in each group. I assign leadership roles to female students and encourage them to lead presentations, which helps build their confidence. This approach addresses the common issue of girls feeling shy or less confident when speaking in front of boys. By fostering an environment where girls can practice their presentation skills and take on leadership responsibilities, I aim to empower them and enhance their participation in class discussions and activities. This strategy not only helps to bridge the confidence gap but also promotes gender equality within the classroom setting. (Chemistry teacher, School D, Interview 16, July 26. 2023, Mbeya)

Motivating more girls to pursue STEM through inclusive learning expands the talent pool and brings diverse perspectives to problem-solving, which is critical for innovation and addressing global challenges. When girls see themselves represented and supported in STEM, they are more likely to remain engaged, pursue advanced studies, and eventually contribute to these fields as professionals, helping to close the gender gap and inspire future generations.

5.4.5. Employing motivating techniques for enhancing girls' learning of science

In this study, it was revealed that teachers fostered a positive learning environment by employing various motivators to encourage learners, particularly girls, in science subjects. These motivators were categorised into intrinsic and extrinsic types, both aimed at enhancing student engagement and enjoyment in learning. Intrinsic motivation was nurtured through encouraging words and exciting assignments, while extrinsic motivation involved tangible rewards such as gifts, recognition, and praise. These incentives were provided when girls demonstrated significant achievements, such as answering questions correctly, completing assignments effectively, or performing well in examinations. Encouraging praises were frequently used in class to acknowledge girls' correct responses, boosting their confidence. Additionally, gifts like exercise books, pens, or books were awarded during school assemblies, where the entire student body and teachers recognised their efforts publicly. A teacher from school A explained how they applied extrinsic motivation to help girls:

> We provide learners with different interesting and challenging activities from the books. Instead of reading notes without having activities, such activities motivate them to learn. (Physics teacher, School A, Interviewee 6, July 17, 2023, Mbeya)

Implicitly, teachers created an environment for girls to get motivated through different activities from the books. The activities motivated them and made them interested in the lessons. A study by the head of school C explained:

> I have an example of a very committed mathematics teacher. He usually asks for things like pens and exercise books for the purpose of using them to motivate learners during teaching. He brings with him the names of those who have improved in his subject. I have come to realise that female

> students are among them. I always support him, and sometimes I even give him money to buy those items. (Head of School C, Interview 11, July 27, 2023, Mbeya)

Moreover, a teacher from school A had this to say:

> I give gifts, especially to those who perform well, for example, those who get grades A to C in their examination. On Fridays, those students who performed well during monthly tests are given gifts in front of others, which helps to motivate them. (Chemistry teacher, School A, Interviewee 7, July 17, 2023, Mbeya)

The significance of these approaches lies in their ability to boost girls' motivation and self-esteem in science learning, a subject where they are often underrepresented or less confident. Intrinsic motivators, such as praise and engaging tasks, help girls develop a genuine interest and enjoyment in science, fostering long-term engagement. Extrinsic motivators, such as gifts and public recognition, provide immediate positive reinforcement, encouraging continued effort and achievement. Together, these strategies create a supportive and motivating environment that empowers girls to excel in science, helping to close gender gaps and promote equity in education. Research by Rachmatullah et al. [75] indicates that combining these motivational strategies fosters interest in learning science, making it essential for teachers to collaborate with school administrations to recognise and encourage students' efforts, particularly among girls.

6. Discussion

Our findings revealed important aspects worth discussing. The study found that girls faced different environmental challenges that had implications for their efforts to learn science and mathematics. First, the issue of stereotypes and cultural norms was a challenge to girls. In Tanzania, a society deeply rooted in male dominance, cultural beliefs and perceptions have fostered stereotypes that associate males with science and females with art-based subjects. Studies by Moss-Racusin et al. [56], Miller et al. [55], and O'Brien et al. [69] explain that the stereotypes often encourage boys from a young age to engage in instrumental and object-oriented play, which can enhance their spatial reasoning skills. Spatial reasoning is a cognitive ability closely linked to performance in mathematics and science, as it involves the ability to visualise and manipulate objects in space, a skill crucial for STEM fields. This early exposure to spatial reasoning activities can contribute to boys' higher representation in STEM programs. At the same time, girls are often steered towards non-STEM fields, perpetuating gender disparities in education and career choices. Mukhwana et al. [58] and Roberts et al. [77] explain that society tends to have wrong attitudes in linking boys and girls to gender differences in ability and interest in science, resulting in the expectations by the society that create environment and experiences that differ by gender and have implications on the growth of interest, confidence and feelings of belonging in STEM among girls. Therefore, such wrong attitudes affect girls' efforts as they make decisions to learn science and mathematics.

Another challenge is the lack of role models in society, which has long been a barrier for girls, particularly in fields like science, where they often lack access to successful women who can provide advice and inspiration. Studies have shown that exposure to female role models, such as scientists, can significantly enhance girls' confidence and encourage them to make informed decisions about pursuing science-related careers. This interaction not only boosts students' self-assurance but also helps them envision a future in STEM fields by challenging gender stereotypes and showcasing the relevance of science in career paths. Researchers like Clawson [13] and Kolker [48] have highlighted the positive impact of inviting professional role models to engage with students, emphasising the importance of these interactions in shaping girls' academic choices and aspirations in science subjects. By seeing successful women in STEM, girls are more likely to believe in their own potential to succeed in these fields, as the presence of role models helps bridge the gap created by societal biases and stereotypes.

Thirdly, the lack of support from family members, such as parents and siblings, significantly hinders girls' ability to excel in science and mathematics. This is exacerbated by societal norms that have traditionally associated science with masculinity, steering girls towards other fields. As a result, girls face substantial barriers in their pursuit of learning in these subjects, making it difficult for them to thrive in environments where they are not adequately supported or encouraged.

The lack of specific curricular documents guiding teachers on how to effectively utilise the learning environment to enhance girls' participation in science and mathematics is another significant challenge to girls' participation in science. Currently, teaching materials primarily focus on inclusive learning strategies without providing clear guidance on how to boost girls' interest in STEM fields. This issue is highlighted in both the 2014 and revised 2023 Education and Training Policies, as well as in secondary school science syllabi. However, Lyimo, Too and Kipng'etich [52] slightly differ from the findings of the study as he identified several critical challenges affecting the teaching environment in community secondary schools, including poor infrastructure, overcrowded classrooms, and a scarcity of teaching and learning materials, which affect both girls and boys in the learning of science and mathematics. Furthermore, Matete [54] found that science and mathematics teachers predominantly employ theoretical teaching methods due to insufficient laboratory facilities in public secondary schools, which results in poor motivation of learners, particularly girls in the related subject.

It was revealed in the study that teachers, being aware of the underrepresentation of girls in science and mathematics, employed a creative approach to foster their participation. By leveraging the physical, cognitive, social, and affective elements of the learning environment guided by Social cognitive learning theory, teachers successfully encouraged girls to engage more actively in these subjects. To address the challenges faced by students in Form Three when selecting subjects, teachers offered advice by guiding girls' decisions, particularly in favour of pursuing science and mathematics. This support was crucial in helping the students make informed choices that would shape their future academic and career paths. Teachers who provide personalised support can help learners grow, achieve their potential, and gain the confidence needed to excel in science and mathematics [68]. While Dost [20] emphasises the positive influence of these factors on STEM motivation, contrasting evidence suggests that intrinsic factors, such as STEM self-concept, may sometimes outweigh external support systems in driving motivation and persistence [23].

Furthermore, Girls were given opportunities to learn science and mathematics even if their performance did not meet the typical entry requirements. Teachers considered not only academic performance but also the learners' interest in these subjects. This approach was designed to promote greater participation among girls, who historically lagged behind boys in both performance and engagement in science and mathematics. By doing so, the aim was not to disadvantage boys but to create a more inclusive environment that encouraged girls to pursue these subjects.

Additionally, girls often hold misconceptions about science and mathematics, which can lead to their reluctance to participate in learning actively. To address this, teachers created a friendlier and supportive learning environment by using diverse motivational techniques and assigning girls specific roles, aiming at boosting their confidence and engagement. This approach aligns with research suggesting that a conducive learning environment is crucial for students to feel comfortable and confident as learners [51]. By fostering such an environment, teachers can help girls overcome their hesitation and fully engage in science and mathematics education. This approach aligns with the country's broader educational goals, as outlined in the 2014 Education and Training Policy [96]. By integrating environmental elements into the curriculum, the government aims to foster a generation of learners who are not only knowledgeable but also competent in solving practical problems.

Additionally, introducing role models can be of great help in improving girls' participation in STEM-related fields [46]. Supporting this perspective, Clawson [13] and Kolker [48] discussed the impact of inviting professional role models to engage with students, especially girls, about the relevance of science in future career paths. This interaction not only boosts students' confidence but also encourages informed decisions regarding their academic choices in science subjects.

Suleiman and Otieno [87] emphasises that a supportive learning environment is crucial for fostering meaningful socialisation and interaction among students studying science subjects. This interaction is pivotal for developing problem-solving skills, which are essential for addressing real-world challenges. Similarly, Ndalichako and Komba [67] likely highlights the significance of such environments in enhancing student engagement and academic outcomes. Aligning with the findings of this study, the study by Babatunde and Olanrewaju [4] emphasises the importance of regular advice to encourage students to pursue STEM-related courses. Mulenga, Daka and Mulenga-Hagane [59] also supports these findings by demonstrating that teacher-related factors, including enthusiasm, significantly influence learners' positive attitudes toward Mathematics.

7. Conclusion and recommendations

Girls face numerous challenges in learning science subjects, which often leads to low motivation and underrepresentation in STEM fields. The study noted that the infrastructure in schools A and B, such as laboratories and classrooms, was not in good condition, which affected both boys and girls in learning science and other subjects. Although teachers employed various strategies to encourage girls' participation in science, fostering genuine interest and success requires a collaborative effort from the entire society. This includes active involvement from the government, families, teachers, peers, and the girls themselves, all working together to create a supportive and conducive learning environment. By addressing these challenges collectively, we can help ensure that girls are empowered to pursue and excel in science subjects.

The study recommends the following to the government through the Ministry of Education, Science, and Culture. Allocating funds to renovate and equip schools with adequate science laboratories, classrooms, and learning materials. Periodic audits of school infrastructure should be done to ensure maintenance and upgrades are done. Developing gender-sensitive science curricula that support teachers in fostering girls' interest in science. Include curricular activities that encourage girls' participation in science learning. Provide professional development programs focused on inclusive teaching practices, emphasising ways to foster girls' interest in STEM subjects.

The society must challenge and change the harmful perception that women cannot succeed in science-related fields. This misconception undermines girls' confidence and discourages them from pursuing studies in science and mathematics. To support and empower girls in these areas, it is essential to organise community workshops focused on dismantling stereotypes about women's abilities in science. These workshops can raise awareness, promote positive role models, and foster an environment that encourages and celebrates girls' achievements in scientific disciplines.

Teachers can play a pivotal role in fostering girls' interest and engagement in science and mathematics by collaborating with parents and the wider community. This collaboration helps raise awareness about the importance of STEM education for girls and encourages positive perceptions of these subjects from an early age. Employing student-centred instructional methods, such as cooperative learning environments, is especially beneficial as they promote collaboration rather than competition, which has been shown to enhance girls' engagement. Additionally, providing individualised feedback and encouragement helps girls develop a growth mindset toward STEM subjects, emphasising that effort and learning strategies lead to success rather than innate ability. Exposing girls to female role models and sharing success stories of women in STEM careers can inspire them to envision themselves in similar roles. Such representation challenges stereotypes and builds confidence. Teachers should also create inclusive classroom environments that use hands-on, real-world problem-solving tasks, fostering curiosity and critical thinking. Moreover, integrating gender-fair teaching materials and ensuring equal participation in STEM activities further support girls' involvement. By implementing these strategies, educators can cultivate a supportive atmosphere that nurtures girls' long-term interest and success in science and mathematics. The study advocates for further research focused on teaching methods that specifically motivate girls in inclusive classrooms, aiming to create a more supportive and engaging learning experience for all students.

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