Barriers and Attitudes Affecting Grade 12 Female Pupils' STEM Education at David Kaunda National STEM Secondary School in Zambia

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ABSTRACT

Aligned with Zambia's commitment to equitable and inclusive education under the Zambia Education Curriculum Framework 2023 and the United Nations Sustainable Development Goals (SDGs 4 and 5), this study critically examines secondary school-based barriers and attitudes affecting and influencing Grade 12 female pupils' participation and retention in STEM subjects at David Kaunda National STEM Secondary School. Despite strong policy commitments, persistent gender disparities and attrition at school level arguably point to gaps in the advancement of girls' STEM education.

The methodology used for the study is a single instrumental case study design. This is because the study sought to investigate in-depth the barriers and attitudes affecting girls' STEM education at the first and model National STEM School in Zambia. A mixed-methods approach with a predominantly qualitative orientation was conducted from July- September 2023. Quantitative data was collected through a semi-structured questionnaire administered to 51 participants, while qualitative data included a focus group discussion (FGD) with 8 Grade 12 female pupils and in-depth interviews (IDIs) with 11 purposively selected key informants from the school and relevant STEM institutions. Data was analysed using descriptive statistics and thematic analysis.

The findings reveal that the vast majority of female Grade 12 pupils opt out of STEM education at the School. The empirical analysis also highlights that weak design, inconsistent implementation and lack of gender-responsive targets affect female pupil's pursuit and retention in STEM education. In addition, the findings also unpack multifaceted barriers to entry, stay and progress affecting female pupils' STEM education.

These include, but are not limited to, entrenched societal expectations and socio-cultural norms about female pupil's inferiority; gender stereotypes rooted in sexism or patriarchal traditional beliefs; female pupil's self-doubt, attitudes and peer-influence; teachers' attitudes which discourage or underrate female pupil's STEM aptitude; inadequate gender responsive infrastructure, limited access to female role models and insufficient academic and psycho-social support. The combined effect of these factors may pose barriers to female pupil's' sustained participation and continued engagement in STEM education.

Consequently, the paper shows that enhancing female pupil's participation and retention in STEM requires coherent, context sensitive, and gender responsive strategies. It recommends strengthening teacher professional development, expanding targeted STEM initiatives for girls, improving infrastructure, and integrating female role models within school systems.

Keywords: STEM education, gender stereotypes, girls' attitudes, barriers, gender disparities, retention, attrition

INTRODUCTION

The Science, Technology, Engineering and Mathematics (henceforth STEM) fields have historically been perceived as masculine dominated disciplines where female pupils have been considered inferior to male pupils [1-4]. These worldviews about girls' place and suitability in STEM education is not new and has had long-lasting and inter-generational setbacks on STEM educational opportunities and outcomes for girls [5][4][3]. For decades, female pupils have grappled with barriers to entry, remain and progress in STEM education and have arguably been discouraged and dissuaded from studying STEM subjects and aspiring to pursue STEM careers by structural, systematic and cultural barriers [4][6].

This is due to a complex labyrinth and interaction of factors creating differential dropping out of female pupils from STEM education [1][5][7][8] such as 'deep-rooted socio-cultural, economic, and institutional barriers' [4:p.57]. Whether deliberately or unintentionally, the continual reduction in the numbers of female pupils at training level, debatably attributed to attrition and 'STEM-avoidance' [8:p.352], raises serious concerns in the lastingness of the gender gap and female pupil's retention in school despite gender parity progress at international and local levels [1-2][7][9].

There exists strong global, regional, and national commitments to promoting gender equity in STEM education [2][6]. At global level, International frameworks such as the landmark Beijing Declaration and Platform for Action and more recently the Sustainable Development Goals (SDGs 4 and 5) emphasize inclusive and equitable quality education. However, significant disparities persist in female pupils participation and retention in STEM subjects across the globe [6][10-11]. Even with the combined worldwide efforts to create the pre-conditions of promoting STEM education for girls, the number of girls who make it into STEM careers globally are largely unmet and remain lower than targeted 50 per cent parity thresholds [11-12]. This is more pronounced in Developing countries where notable imbalances in STEM education are by far less and range between 25 to 30 per cent overall [10].

At regional level, agendas such as the African Union's Agenda 2063 and the New Partnership for Africa's Development (NEPAD) highlight the importance of STEM in driving socio-economic transformation [13-14]. Notwithstanding efforts to promote inclusive STEM education for female pupils, the impact of regional interventions remains uneven due to disparities in national capacity, resource allocation, and policy implementation [15-16]. This suggests that while policy frameworks exist, their translation into meaningful classroom practice in retaining girls in STEM education remains inconsistent across contexts [6].

At the national level, Zambia's Education Curriculum Framework (2023) further reinforces these commitments by prioritizing competency-based STEM pathways as critical to national development [16]. However, the translation of these policy aspirations into meaningful outcomes at the school level remains uneven and insufficient [17-19]. In addition, female pupil's apathy and disinterest towards STEM subjects has been growing and veering towards non-STEM subject selections and career pathways [20-21]. Studies attribute this trend to a combination of socio-cultural, institutional, and individual factors, including gender stereotypes, lack of confidence among girls, teacher biases, limited access to resources, and inadequate school infrastructure [10][22-23]. A study conducted by Ndhlovu [9] titled 'Attitudes of girls towards mathematics in selected secondary schools in Lusaka and Mazabuka' showed that Mathematics, [as a STEM subject], was viewed as a difficult subject by female pupils at David Kaunda Technical School (former name). As a consequence, the female pupils developed a poor attitude towards the subject. Other factors which conditioned this attitude include societal misconceptions that girls are weaker than boys in mathematics, societal stereotypes and teacher discouragement. In a similar vein, Ziwa's [24] work investigated the 'Factors affecting the participation of girls in technical subjects: the case of David Kaunda and Hillcrest National Technical High Schools' between 2002 and 2006. The findings revealed that during that time period, the number of female pupils enrolled in STEM subjects at David Kaunda Technical High School (former name) declined by 29 per cent. The rapid decline was attributed to inter alias poor attitudes by female pupils who were affected by peer pressure, teacher encouragement to take non-STEM subjects like home economics and management, discouragement relating to the perception that STEM subjects are manly and the desire of girls to marry immediately after completing Grade 12. Evidence from Mayumbwayila's [25] study showed that 75 per cent

of the female Grade 12 pupils have a negative attitude towards STEM education and prefer to discontinue the STEM career pathway post-secondary school education. These studies show a recurrent trend in the unsatisfactory retention of female pupils in STEM subjects and education.

Additionally, much of the existing research in Zambia has focused on macro-level analyses in higher education or broad national trends, with limited attention given to the role of school systems in shaping girls' STEM participation at the secondary level [26-28]. This represents a critical gap, as secondary education is a pivotal stage where subject choices are made, interests are developed, and career pathways are shaped [6][9][20]. Understanding how school-level strategies, practices, and environments influence girls' uptake and retention in STEM is therefore essential for designing effective interventions that align with national and international policy goals [16][29].

This creates a critical gap in understanding the effectiveness of secondary school-based interventions and the extent to which they are aligned with gender-responsive and context-specific needs [30]. Particularly, there is insufficient empirical evidence on whether current strategies implemented in STEM-focused secondary schools are adequately designed, consistently applied, and capable of addressing the structural and socio-cultural barriers faced by female pupils [12][16][19][26]. The cumulative effect of filtering out girls in the STEM education is plausibly detrimental, in that, it not only accentuates the gender representation gap but also fundamentally affects girls' contribution to providing innovation outputs to drive the sustainable development process [10-11][30-31].

It is against this backdrop that the study investigates the barriers and attitudes which affect the advancement of girls' STEM education at David Kaunda National STEM Secondary School. The first part provides a brief on the history and rationale for selecting David Kaunda National STEM Secondary School as the case study of the research. Aside from being the first technical School, David Kaunda was piloted as the National STEM School by the Ministry of Education providing equal STEM education to both girls and boys. However, as the study shows, girls' attrition rate is a major source of concern in narrowing the gender gap in STEM education even though efforts have been made to enhance gender parity. The second part delves into the methodology which was used to conduct the research. It justifies why the single instrumental case study design was used to get an in-depth understanding of a specific bounded case, which is, the barriers and attitudes affecting girls' STEM education at the first and model National STEM School. This part also states why the mixed-methods was selected as a befitting approach for the research. In the third section, the findings are presented and analyzed within global, regional, and national policy frameworks. Here, the study reveals, among other findings, that there is a disconnect between the translation and effective implementation of policy intentions against girls' school-level realities which affects their attitudes and retention in STEM education. The findings also unpack the barriers to entry, stay and progress in STEM education pathways which influence girls' decisions to remain or change their core subjects from STEM to less demanding ones. The paper concludes with recommendations on how gender-responsive strategies could be used to improve girls' interests and retention in STEM education.

David Kaunda National STEM Secondary School – in Context

To unpack the barriers and attitudes which may affect girls' STEM education at David Kaunda National STEM Secondary School, it is important to provide a brief account of how the School evolved in the provision of technical education first for boys and later girls since its inception in 1934 [9].

To begin with, David Kaunda, the first Technical and later STEM Secondary School, was originally known as Hodgson Training School for boys. At the time, the School's mandate was to provide technical and hands-on education in carpentry, bricklaying, leather and metal work for children of soldiers located across the School [9]. The infrastructure, that is, the hostels, specialized rooms, machinery, equipment and laboratories were designed with boys in mind without consideration for possible girl enrollment in the future [9][27][30].

In 1965 the name of the school changed to David Kaunda Technical School in honour of the father of the first Republican President of Zambia Reverend David Kaunda. It remained the premier boys' technical boarding school which only accepted the top performing boys in the Grade 7 National Examinations from all the

provinces in the Country until 1993 when the first cohort of girls was enrolled [9]. This was after the Ministry of General Education expanded the education policy to include girls in technical education [29-30].

The School was later renamed David Kaunda National STEM Secondary School in October 2020 and piloted as the model national STEM school in line with global, regional and national commitments [30]. However, despite efforts to bridge gender disparities in STEM education at the School, the number of girls in relation to boys remains disproportionate. This is further exacerbated by the barriers and girls attitudes which affect low retention numbers of girls in STEM subjects [31].

METHODOLOGY

Study design

Methodologically, the study was guided by the "single instrumental case study" as defined by Creswell [31:p.73] under the umbrella of instrumental case study developed by Stake in 1995 [32-35]. Here, the researchers selected a bounded case following the identification of the unique research issue, that is, the factors affecting girls' retention in STEM education at David Kaunda National STEM Secondary School, the first and national STEM Secondary School in Zambia [36-38]. This was a mixed-methods study with a predominantly qualitative orientation that sought to investigate the barriers and attitudes affecting girls' STEM education at David Kaunda National STEM Secondary School.

Population, sampling, and recruitment

The study population included Grade 12 female pupils, school administration and teachers, and individuals from the National Science Centre (NSC) and Zambia National STEM foundation (ZNSF). Survey participants were randomly selected from the school class lists by (GW) and (BS), and then located in their classes with the help of the school administration, class teachers, and matrons. On the other hand, focus group discussion (FGD) and IDI participants were purposively sampled with the help of the school matron, guidance and counselling teachers, and supervisors at STEM institutions to ensure variation among Grade 12 female pupils, teachers, and STEM institutions. The Grade 12 female pupils were selected because they are on the verge of completing their Secondary School education and selecting their preferred career pathways, and a cohort which represent a crucial time when girls transition from the adolescent stage of life to adulthood and are faced with socio-economic forces and barriers which affect their decisions to remain in STEM fields [10]. While IDI participants were selected due to their experience and expertise in STEM.

Data collection

We collected data using IDIs, FGD, and a survey conducted July to September, 2023. Both the IDI and FGD guides were developed by (GW) and (BS) based on literature review. Interview questions focused on existing strategies and initiatives implemented by the school, participation and uptake of STEM subjects, effectiveness of school programs and/or initiatives, and challenges faced by schools in promoting girls' uptake of STEM subjects. While survey questions were developed based on data collected from the IDIs and FGDs. We conducted 11 IDIs with teachers (n=8) from different departments including Design and Technology, Pure Sciences, Mathematics, Counselling, and Social Sciences, and an administration member (n=1) at the school, as well as an official from Zambia National STEM Foundation Official (ZNSF) (n=1) and National Science Centre Official (NSC) (n=1). A FGD (n=1) was conducted with eight Grade 12 female pupils. Additionally, using Slovin's formula, a total of 61 Grade 12 female pupils were randomly selected to participate in the survey, of the 61 pupils eligible to participate, 51 participated in the survey. The 10 pupils who did not participate had either not yet reported to school or chose not to participate. A semi-structured questionnaire was administered by (GW), with some participants being offered to complete questions on their own to enhance privacy. The questionnaire included modules on socio-demographics, strategies implemented to enhance girls' participation in STEM subjects, and effects of established school strategies in enhancing girls' uptake of STEM subjects. All data were collected in English with data collection activities held in spaces where participants felt safe to be in including offices, and classrooms (see table 1 for details).

Table 1. Categories of participants, demographics and data collection methods

	Respondent	Organisation	Research Instrument Used	Recruitment Method	Number
Key Respondents (Qualitative Data)	1. National Science Centre (NSC)	Ministry of Education	In-depth Interview	Referral from Superior	1
	2. Zambia National STEM Foundation	NGO	In-depth Interview	Referral from Superior	1
	2. Female Teachers (Irrespective of whether they were STEM teachers)	David Kaunda National Stem Secondary School	In-depth Interview	Across all department	3
	4. Male Teachers (Irrespective of whether they were STEM teachers)	David Kaunda National Stem Secondary School	In-depth Interview	Across all departments department	6
Total					**11**
Primary Respondents (Quantitative Data)	Girls taking STEM subjects	David Kaunda National Stem Secondary School	Semi-structured questionnaires	In-person and availability	51
Total					**51**
Focus Group Discussion (Qualitative Data)	Girls taking STEM subjects	David Kaunda National Stem Secondary School	Interview guide	Across all Grade 12 classes	8
Total					8

Table 1: Research Methodology and Tools

Source: Developed by Authors for this study

Data management and analysis

All IDIs and FGDs were audio recorded. Field notes were also taken by (GW) using a template and then typed in microsoft word immediately after data collection, and audio recordings were transcribed verbatim. All qualitative data were analysed using the thematic analysis approach, which employed inductive reasoning to identify, analyse, and report themes in the data [39]. The qualitative analysis process for this study involved several steps, starting with (GW) reading through all 12 transcripts where important codes necessary to answer the research questions were identified and defined, and a draft code book was developed which was later discussed with the senior author (BS). GW manually coded the rest of the transcripts, often meeting with the study team (BS), (MMM) and (NM) to discuss and update the code-list. After the coding was done, GW developed code reports for all themes. Conversely, the quantitative analysis process for this study involved several steps, starting with collecting data using an electronic mobile platform called Kobo collect. Inbuilt validation checks were included in the Kobo collect to ensure that clean data was collected. After data collection, data was exported to Microsoft Excel for further data cleaning and analysis using descriptive statistics. Descriptive statistics, such as numbers and percentages, were used to represent the quantitative data, which were presented in tables or graphical formats.

RESULTS

The findings of this work provides evidence of the barriers and attitudes affecting Grade 12 female pupil's STEM education at David Kaunda National STEM Secondary School.

Characteristics of Respondents

Age of Respondents

The data presented in **Table 2** below indicates that 16.55 was the mean age of the respondents. Among the 51 Grade 12 girls that participated in the survey, the most common age of the respondents was 16, with the oldest respondents being 18 and the youngest being 15. This shows that on average, pre-adults constitute the Grade 12 cohort at the School and are at the nexus of major life decisions regarding their career pathways.

Table 2: Age of Respondents

	Age
Mean	16.55
Mode	16
Std. Deviation	0.7
Minimum	15
Maximum	18

Source: Fieldwork survey 2023

Option Subjects taken by the Respondents

The decision to select optional subjects by the Grade 12 girls revealed that about 65.29% combined preferred non-STEM subjects whereas only 34.71% took STEM subjects. Incidentally, the findings also showed that of the 51 respondents, the vast majority, i.e., one in four girls took History as their first option subject compared to 5% who took the least selected subject, Design and Technology, a STEM subject. The second most popular option among the girls was Agricultural Science accounting for about one tenth of the total sample size. This was followed by Geography and Civil Education at approximately 12% apiece. Religious Education constituted roughly 10% whereas the other two STEM subjects, Computer Studies and Additional Mathematics represented 9% and 8% respectively. The second least option was Food and Nutrition making up 9 respondents. These findings indicate that the uptake of STEM subjects among the Grade 12 girls at the School is low in comparison to non-STEM subject. See Figure 1 for details.

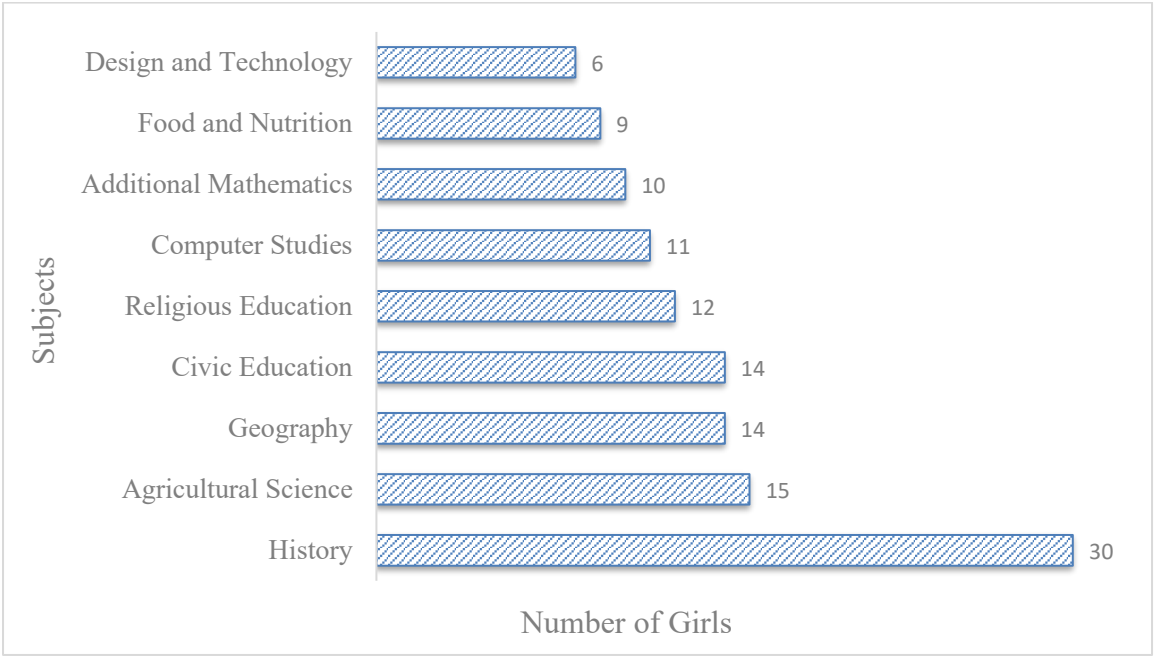


Figure 1: Option subjects taken by the respondents

Source: Fieldwork survey 2023

Challenges faced by the School in enhancing girls' uptake of STEM subjects

In order to have a better understanding of the common challenges faced in enhancing girls' participation in STEM subjects, the respondents were asked to select and state the challenges they felt discourage girls from participating in STEM subjects. A list of challenges derived from existing literature that hinder the participation of female pupils in STEM subjects was compiled and the participants identified challenges applicable to them and their School. Participants were also asked to include any other challenges not listed but deemed relevant. The survey results revealed nine distinct challenges. The figure below illustrates these specific challenges in chronological order.

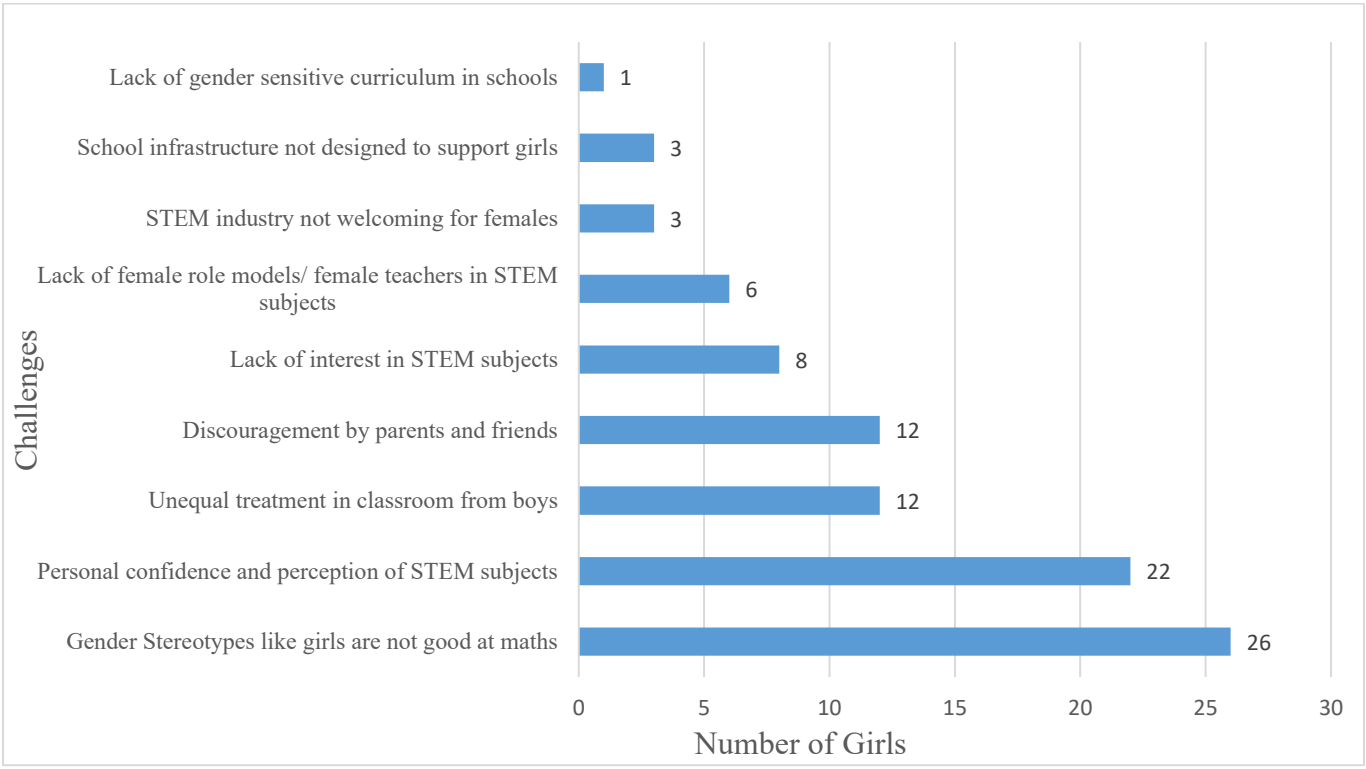


Figure 2: Challenges that discourage girls from participating in STEM subjects

Source: Fieldwork survey 2023

The **figure 2** above reveals the nine challenges, each with its corresponding frequencies: gender stereotyping of the girl child in STEM, represented by (n=26); girl child's personal confidence and perception of STEM subjects, (n=22); unequal treatment of the girl child from the boys in the classroom, (n=12); discouragement of the girl child by parents and friends, (n=12); lack of interest in STEM subjects, (n=8); lack of role models in STEM, (n=6); STEM industry being unwelcoming for females, (n=3); school infrastructure not being designed to support girls, (n=3); and a lack of a gender-sensitive curriculum in schools, (n=1).

The findings revealed that girls face several challenges as far as participation in STEM subjects is concerned. The most common challenges that emerged from these survey findings were gender stereotyping of the girl child and girl child's personal confidence and perception of STEM subjects. Using findings from interviews and the FGD, the study unpacks the findings from the survey as overarching themes.

Gender Stereotyping of the girl child in STEM

Gender stereotyping, noted by 26 survey respondents, was stated as one of the major challenges experienced by girls in STEM. Cultural and societal stereotypes, mentioned in both interviews and the FGD were identified as some of the main factors in discouraging girls from pursuing STEM subjects. During the FGD, the girls voiced their dissatisfaction with negative assumptions about their abilities in subjects like Mathematics, Design and Technology and Physics.

A girl during a FGD mentioned that,

"I feel most people are only not interested in Design and Technology and Architecture, because they believe builders can only be men. I feel like they can do it but are scared of stigmatization…to be isolated [or]… to be looked at in a bad way."

[Girl_13-15 years].

These reasons heavily influence the Grade 12 girl's choices as far as subject selection is concerned.

Additionally, certain participants, particularly male teachers, exhibited attitudes reflecting these stereotypes. For example, one teacher claimed that it was scientifically proven that girls lacked numerical skills and preferred home economics as they supposedly 'loved cooking.'

The following excerpt provides additional insights into these findings:

"More girls opt out of Science because scientifically women and girls are not good at numbers, it is not a feminine thing but it is scientific evidence…There are more girls in the home economics club, maybe it is because girls love cooking. I think very few girls take up STEM subjects or STEM careers because of factors like labeling, they think this is for males.

When you look at the Industry, those doing these metal fabrication aspects they are male, so girls would think 'ivi ni vaba muna ivi', [translated to mean this is for men]. Over the years, we have labelled to say, these courses like engineering they are hard, so let the male[s] do it, maybe they feel the woman is for Nursing and the male is not."

[Man_52-54 years].

Furthermore, cultural norms, such as predefined gender roles confining girls to household tasks, and perceptions of male dominance in STEM careers like Engineering and Construction, were further noted as further constraints by some teachers and officials. However, some teachers argued against gender stereotypes posing a negative impact on the girls, noting instances where girls outperformed boys.

Girl child's lack of personal confidence and perception of STEM subjects

The lack of personal confidence and negative perceptions of STEM subjects among female students, as indicated by 22 respondents in the survey, was deemed as a significant mental barrier to female participation in STEM subjects. IDIs and the FGD further highlighted the influence of experiences and perceptions on girls' decisions to avoid STEM subjects, with gender stereotypes reinforcing these barriers. Also, the Zambian education system's emphasis on points rather than subject combinations for university admissions was said to influence pupils' subject choice, including girls, to opt for perceived easier subjects like home economics to maximize points. Additionally, both teachers and pupils highlighted various reasons for girls' avoidance of specific STEM subjects, including perceived difficulty, concerns about time spent on practical tasks in the workshop, hence, affecting their study time, and assumptions about the benefits of taking subjects like additional mathematics for university admission in natural sciences.

A teacher during an IDI said that:

"Universities have a tendency of selecting pupils based on points and not subject combination. It does not matter if one did pure sciences or not, or if they were taking technical subjects or not. Depending on the number of points you get at Grade 12, you can do Medicine, Engineering and the like. Because of the way the system is put, [pupils] would rather do something that is easy and gives them more points"

[Woman_40-42 years].

Gendered partiality in the classroom

Echoing the findings of the survey (where 12 respondents highlighted the unequal treatment of the girl child in the classroom by some teachers favoring boys), the girls in the FGD, in one accord, mentioned that some teachers, especially female teachers, often addressed them in a way that implied they were incapable of accomplishing certain tasks in class when compared to boys. They further stated that some teachers seemed more focused at demotivating and embarrassing them in front of their male peers rather than providing encouragement, which occasionally led to them potentially disliking the subjects taught by those teachers. Furthermore, all the girls concurred that most teachers used boys as the standard for ideal pupils, even when there were girls who were performing better than the boys in those very subjects. This unequal treatment in the classroom was cited as a demotivating factor. The following quotes further elaborate these findings:

"How the teachers talk to us, they tend to push it in our minds that we can't do certain things"

[Girl_13-15 years].

Another pupil buttressed the notion that boys are given preeminence over girls by adding that,

"…The example is always boys, there could be girls who are passing but they will point at a boy rather than a girl (all agree). They would rather have a male example than a female example"

[Girl_16-18 years].

Discouragement of the girl child by parents and friends

The influence of parents and the household environment (highlighted by 12 respondents in the survey) on girls' interest in STEM was also mentioned as a challenge which emerged as a constant theme in both interviews and the FGD. Participants, including girls and teachers, emphasized the significant role parents play in shaping girls' subject choices, highlighting the need for parents to be better educated with regards to STEM. Some parents were noted by some teachers to have inadequate knowledge about STEM subjects and careers and were seen to negatively influence their children away from STEM careers, sometimes driven by their own negative experiences with certain subjects like mathematics. For instance, a mother struggling with mathematics in her school years might unintentionally give the impression that math is inherently challenging for girls. Furthermore, during the FGD, a minority of girls shared their experiences of feeling demotivated whenever their male classmates expressed surprise at their participation in certain STEM extracurricular activities like JETS fair.

In contrast, a few girls and some teachers highlighted the positive influence of parental support on girls' STEM uptake, noting that those who were drawn towards STEM subjects like Design and Technology often had parents with backgrounds in technical schools or STEM fields.

The excerpts below highlight some of these findings:

"And sometimes again, these options that we take.... what I want to do my parents don't want me to do it, at times it is not always our decision, our parents are the ones who tell us, just go into this class, so we don't really have a say sometimes"

[Girl_16-18 years].

"Most of the ones who were here at junior level and have continued with design and technology at senior level you find that their parents or relative went through a technical school. Then they are aware, they say no my father actually did design and technology so he encouraged me"

[Woman_ 37-39 years].

Lack of interest in STEM subjects

Both quantitative (highlighted by 8 survey respondents) and qualitative findings, showed that female pupils' choice to either pursue or avoid STEM subjects was also influenced by their subject interests. A few pupils expressed their lack of interest in STEM careers and stated their desire to pursue careers in social science fields like law, business, or entertainment industries instead.

Likewise, some teachers echoed this sentiment, noting that many girls disliked the hands-on, technical components of STEM subjects due to fears of getting hurt. It was also noted that boys tended to gravitate more toward engineering courses, whilst most girls showed a preference for medical courses.

The following quote may help in further elaborating these findings:

“Honestly speaking I am not interested in pure sciences, and also I want to study law and I feel like it won't help me”

[Girl_16-18 years]

Lack of role models in STEM

The limited presence of female role models in the STEM field (highlighted by 6 respondents in the survey), both within the school and in the broader STEM field, was seen in interviews and the FGD as having a negative impression on how girls perceived STEM as a predominantly male field. Some teachers pointed out that the scarcity of female teachers compared to male teachers in the STEM departments at the School could potentially deter girls from pursuing STEM subjects. For instance, the Mathematics Department had just one female teacher and nine male teachers, while the Science Department had six female teachers and thirteen male teachers.

In contrast, the Social Science Department was noted to have a higher proportion of female teachers compared to males. Likewise, most teachers provided valuable insights that it was uncommon for female mentors in STEM fields to visit the School and specifically inspire and guide girls regarding STEM subjects.

As attested by a female teacher, “The limited number of role models and females in technical subjects could have a negative impact on girls. Because in Social Science where I am there are more females but in Design and Technology there is one female, the rest are male”

[Woman_ 37-39 years].

Supporting this, some girls in the FGD stated that if such mentoring sessions were conducted, it would greatly encourage more pupils to choose STEM subjects.

STEM industry being unwelcoming for females

In line with survey findings, some teachers believed that the under-representation of women in STEM careers (as reported by 3 survey respondents) could discourage girls from studying STEM subjects. They voiced concern that girls might regard STEM careers as unwelcoming for females, as highlighted by a teacher in the following quotation.

“This could be maybe due to a lack of interest on the pupil’s part, or they have that mindset of saying that some of these subjects are for men, I cannot go anywhere with them. So, it is better if I do something which will lead me into what I can do. They feel the Industry out there is not welcoming for females”

[Man 28-30 years].

Nevertheless, a few teachers held the belief that this scarcity of female role models could motivate girls to take on the challenge of pursuing a career in STEM.

School infrastructure and gender-differential needs

While only three respondents in the survey highlighted infrastructure challenges as a barrier for girls pursuing STEM, most of the participants in the interviews and FGD viewed infrastructure as a significant challenge. Among the many concerns raised by the girls, the shortage of accommodation due to the limited number of hostels for girls when compared to the boys was particularly emphasized as the main infrastructure challenge at the School. During the FGD with the girls, they expressed their disappointment and dissatisfaction with the School having a higher cutoff point for girls due to this shortage rather than a belief in their abilities and gender-differential needs. This gives an impression that girls are viewed as an after-thought or the fulfillment of a policy requirement. As a consequence, it affects their sense of belonging and declining interest in STEM education [37].

The girls also collectively expressed their discomfort and demotivation from being the minority in classes, especially in STEM subjects like Design and Technology classes, which led to some of them switching to classes with more female peers like home economics.

A girl during the FGD shared her perspective:

"Honestly looking at the ratio of males to females in this School, when you look at it, it is a ratio of one to three. For every girl there is three boys, as you can see, we have two female hostels and six male hostels. And one male hostel caters for more males than one female hostel does. Which to some extent is understandable because initially this was a boy's school. But from that time, they have not built any female hostels which does not make sense, nothing has been done to build more hostels for girls. Initially, when I came here, I thought the cut off point for girls was higher because they believed in us, but it is just because they have no space. Which is not good, which should not be the case. Sometimes it is very uncomfortable to walk into a class and see that females are the minority. Sometimes you can't even answer a question because you will just hear murmuring from the boys (all agree). And boys have so many inside jokes just like females do. Except they are the majority. It makes us feel less expressive in a class (all agree). Sometimes I can't even know. If number 4 was in twelve two, I can't even visit because there are three of them in there. It doesn't even give the morale to do anything"

[Girl_16-18 years].

Likewise, most teachers echoed these concerns, noting an imbalance between the number of boys and girls at the School, with many high achieving girls shunned from being enrolled at the School due to the limited number of bed spaces. Additionally, some teachers cited lack of and/or insufficient STEM learning resources due to financial constraints from the Government, including delayed fund disbursement and imposed restrictions on utilization of funds is another infrastructure challenge. These challenges were said to have not only affected academic resources but also extracurricular activities like clubs, affecting the quality of education delivery and potentially leading to some pupils opting out of sitting for Pure Science exams.

Lack of a gender-sensitive curriculum and expertise in schools

In alignment with the survey findings, the absence of a gender-sensitive curriculum in schools, as mentioned by one survey respondent, did not emerge as a significant challenge during interviews and FGD. Instead, most girls stressed emphasis on the ineffective teaching methods and the focus by some teachers on completing the syllabus. Likewise, these sentiments were equally shared by some teachers who emphasized the lack of STEM teaching skills by some teachers, especially at primary level.

To counter this, some teachers stressed the need for additional training, starting with the National Science Centre (NSC) officials, a Centre spearheading and overseeing STEM at secondary level in Zambia. Additionally, a few teachers mentioned that this knowledge gap became evident during the implementation of the STEM programme in 2021, leading to confusion due to teachers' limited understanding of the field. Also, a shortage of experts at the primary level imposed an additional burden on secondary level teachers, especially when external pupils lacked STEM backgrounds, potentially explaining the low enrollment of girls in subjects

like Design and Technology. Lack of motivation among teachers was also mentioned, which was primarily caused by minimal STEM professional development. Furthermore, few teachers, especially females, were said to choose teaching subjects like physics and agricultural sciences. This trend was attributed to some Higher Institutions of Learning's shortcomings of "failing" students, and it was argued that the approach needs to be changed.

The following quote might provide additional insight into these findings:

"There are very few teachers also teaching Agric[ulture], we are encouraging students to go to college and take up these science subjects. Even physics they are very few, even female teachers of physics are very few, but for biology and chemistry there are more. This could be that UNZA has this mentality of failing people. UNZA needs to change its mentality. Management needs to change the way they do things; the lecturers should change their mentality. I think they are the reason why we have very few teachers"

[Man_ 46-48 years].

Besides the findings, interviews and the FGD revealed additional key challenges limiting girls' participation in STEM subjects. Several school policies were said to discourage some girls from pursuing STEM subjects. Some teachers stressed the school's practice of placing high achieving Design and Technology pupils from primary level into pure classes at the secondary level, assuming that these classes were reserved for top performing pupils contributed to the limited presence of girls in STEM classes like Design and Technology.

A teacher during an interview expressed:

"The Design and Technology HOD complained that we have a lot of our own students who are at junior level doing Design and Technology, but when these students write their exams, most of the students who will get higher marks at Grade 9 are from these technical classes. But when it comes to allocating classes to seniors these guys are taken to pure classes and not technical classes. It is this year that we have made a deliberate policy to say let's teach all our Grade 10 going up, pure sciences. They are usually pushed to pure classes because of the perception that pure classes require higher achievers"

[Man_ 43-45 years].

Furthermore, dissatisfaction with the compromised state of the school system was expressed by most teachers, with concerns about the school enrolling pupils below the school's admission cutoff points due to connections or influence. This resulted in some girls being placed in home economics classes, as they did not meet the qualifications for STEM classes.

A teacher mentioned:

"Where you find a lot of girls in class it is maybe those where they are doing maybe home economics. This is because they also look at results. Despite the cutoff point being higher for girls, I think the system has been compromised where, now that you know me, you use me as a connection to bring your child here despite not being qualified. A good proportion of our pupils actually come from within Lusaka here. You find that when those in distant places are accepted like in Gwembe, they fail to report here. So more pupils choose to write physical science over pure science because of the issue of compromise that I mentioned earlier. We have more students that are not able, those who are not able are the majority whilst those who are able are the minority. It's not based on gender even boys. You even get surprised that how you can have a child like this here"

[Man_ 40-42 years].

Likewise, the school's practice of placing pupils in specific classes to take specific subjects during enrolment based on grades rather than interest was identified as a factor leading some pupils pursuing non-STEM careers after completing secondary school. During the FGD, one participant emphasized that this practice was a key

reason why some pupils opted out of STEM careers. The following excerpt further elaborates this in her own words:

"When we were coming here, our Deputy then, was assigning classes to us, we didn't have a say in it. She was assigning according to the subjects you used to take in junior secondary. And let's say you wanted to change like you career pathway because you feel you have more interest in the other career path, you can't because you have been assigned the class"

[Girl_13-15 years].

Suggested Measures by the Pupils to Encourage Girls' Participation in STEM subjects

During the Focus Group Discussion, the girls put forward some ideas for increasing their involvement in STEM subjects. They proposed making the school environment more enjoyable by introducing more hands-on activities within the School. They expressed a desire for practical activities both within the classroom and as part of extracurricular programs, which would allow them to learn in an enjoyable manner without being subject to grading. This therefore necessitates the need for the Government to reinstate the STEM Programme and professional development opportunities for teachers in STEM subjects to enhance their skills and foster inclusive classrooms. Also, there was a call for David Kaunda National Stem Secondary School's administration, in collaboration with NGOs and the Government, to revamp STEM competitions, ensure more girls participated in the only effective strategy at the school 'JETS', establish organized communication channels with pupils to amplify their awareness and involvement in STEM activities, establish mentorship programs for the girls in STEM fields, and allocate resources to improve infrastructure, including girls' accommodation, labs, and technology access.

"What can be done to make everyone feel included in JETS is the introduction of more activities. Like we can be given more practicals to do, maybe they won't grade us, but they would help us improve. This could be both extracurricular activities and class"

[Girl_16-18 years].

"We do practicals in class but maybe if they could be more, the ones we do we are graded on. Maybe these ones could be like to express ourselves and to find like more good ideas within the practicals. Like more access to the JETS lab and teachers helping us with those things"

[Girl_16-18years].

DISCUSSION

The findings of this study reveal a complex interplay of societal, institutional, and individual factors that hinder Grade 12 female pupil's participation and retention in STEM subjects at David Kaunda National STEM Secondary School. At the core of these challenges are entrenched gender stereotypes, cultural biases, and the absence of supportive environments both at home and in school. Consistent with previous research [15] [38], societal and cultural norms were found to discourage girls from pursuing STEM fields traditionally perceived as male-dominated, highlighting the urgent need for targeted interventions that address these biases at both community and institutional levels.

The study showed that the retention of female pupils in STEM subjects and education is low with the vast majority of the girls selecting non STEM subjects. The female Grade 12 pupils were also pressured to opt out of STEM subjects by their peers and societal forces. This could be due to the stereotypical perception that girls lack the caliber and self-confidence to handle STEM subjects. Additionally, STEM subjects were considered to be more involving for girls in terms of assimilation and time. As a consequence, they preferred to change their core subjects to arguably easier non STEM subjects resulting in the discontinuation of the STEM pathway by the girls. This supports Ndhlovu [9], Ziwa [24] and Mayumbwayila's [25] work which showed that there has been a recurrent attrition of female pupils in STEM subjects over time. These studies

also corroborated the findings of this research that girls switch to non-STEM subjects due to lack of self-confidence, peer pressure and the perception that STEM subjects are difficult.

Within classrooms, unequal treatment and implicit teacher biases emerged as significant hindrances. Professional development for teachers was identified as a critical strategy to promote inclusive pedagogy and mitigate gendered discrimination [39]. Moreover, the scarcity of specialized STEM teachers, particularly female educators, underscores the need for targeted training programs to enhance teacher competence and confidence in delivering STEM education effectively. Parental and peer influence further shape girls' perceptions and engagement with STEM subjects. Parental beliefs, prior experiences, and peer attitudes can either motivate or demotivate girls, suggesting that interventions must extend beyond schools to include community engagement and awareness campaigns [20][38]. These results corroborate previous studies at the same school which revealed that teacher's biases and parental traditional views discourage and steer girls away from STEM education [9][26-27].

Structural and infrastructural challenges also play a critical role. Limited access to essential STEM resources, including laboratory equipment, computers, and reliable internet, constrains both teaching and learning [22][40]. Financial and operational pressures on schools often lead to prioritisation of humanities and social sciences over technical subjects, indicating the need for government incentives and partnerships with private and non-governmental stakeholders to sustainably support STEM education [23].

An additional critical dimension emerging from the study is the role of financial constraints in shaping girls' participation and pathway choices in STEM subjects. STEM education, particularly at the secondary level, is often resource-intensive, in some cases requiring additional user fees to support practical components. In contexts where households face economic limitations, these costs can significantly influence subject selection, with learners, especially girls being steered towards less resource-demanding subjects perceived as more affordable [19][26]. This dynamic is further reinforced by broader socio-cultural norms, where families may prioritize investment in boys' education in technical fields while viewing girls' education through a more conservative or cost-sensitive lens [40-41].

Finally, the study emphasizes the importance of pupils' intrinsic interest in STEM, shaped by exposure to role models, hands-on learning, and supportive policies. Barriers embedded in school practices and systemic flaws such as grade-based class allocation and insufficient early exposure to STEM further limit girls' participation. These findings corroborate Bandura's [42-44] Social Cognitive Theory, which emphasizes the interaction between individual self-efficacy, environmental influences, and behavioural outcomes. Overall, the study demonstrates that enhancing girls' participation in STEM requires comprehensive interventions addressing societal attitudes, teacher practices, resource allocation, and systemic education reforms.

CONCLUSION

This study critically examined the factors which affect girls' participation and retention in STEM subjects at David Kaunda National STEM Secondary School, within the broader context of Zambia's commitment to gender equity in education as articulated in the Zambia Education Curriculum Framework (2023) and global frameworks such as the Sustainable Development Goals (SDGs 4 and 5).

The findings reveal that while policy frameworks and institutional intentions to promote STEM participation among girls are well established, their translation into meaningful and sustained outcomes remains limited. Interventions such as the JETS Club demonstrate the potential of structured, learner-centred and practice-oriented approaches in enhancing girls' interest and engagement in STEM. However, the overall effectiveness of school-based strategies is constrained by fragmented implementation, limited gender responsiveness, and insufficient alignment with the lived realities of female learners.

Importantly, the study highlights that barriers to girls' participation in STEM are not isolated but are deeply interconnected across multiple levels. At the socio-cultural level, entrenched gender stereotypes and community expectations continue to shape perceptions of STEM as male-dominated fields. At the institutional level, inadequate infrastructure, limited access to learning resources, and insufficient teacher preparedness

undermine the delivery of inclusive and engaging STEM education. At the individual level, issues of self-confidence, motivation, and identity further influence girls' subject choices and persistence.

These findings point to a critical disconnect between policy aspirations and implementation realities. While Zambia's education reforms emphasize inclusive, competency-based STEM pathways, the absence of coherent, well-coordinated, and gender-responsive implementation strategies at the school level limits their impact. This suggests that achieving gender equity in STEM requires moving beyond policy formulation towards strengthening institutional capacity, accountability mechanisms, and context-sensitive interventions.

Ultimately, the study reiterates that enhancing girls' participation and retention in STEM is not solely an educational challenge but a systemic one that requires coordinated action across policy, school, and community levels. Addressing this challenge is essential not only for achieving equity but also for unlocking the full potential of Zambia's human capital in driving innovation and sustainable development.

Policy Recommendations

Drawing on the findings, this study proposes the following policy and practice-oriented recommendations aimed at strengthening girls' participation and retention in STEM subjects:

Strengthen Gender-Responsive Teacher Professional Development

The Ministry of Education should institutionalise continuous professional development programmes that equip teachers with both STEM pedagogical skills and gender-responsive teaching approaches. Training should focus on addressing implicit biases, promoting inclusive classroom practices, and enhancing teachers' capacity to support girls' confidence and engagement in STEM subjects.

Expand Targeted and Structured STEM Programmes for Girls

Successful initiatives such as the Junior Engineers Technicians and Scientists (JETS) Club should be scaled up and complemented by additional structured programmes specifically targeting girls, including STEM camps, competitions, and innovation hubs. These programmes should be intentionally designed to address gender disparities and provide safe, supportive spaces for girls to explore STEM.

Institutionalise Mentorship and Role Model Programmes

Schools should establish formal mentorship programmes linking female students with women in STEM careers. Increasing the visibility of female role models can play a critical role in enhancing girls' aspirations, self-efficacy, and persistence in STEM pathways.

Strengthen School and Community Engagement to Address Socio-Cultural Barriers

Efforts to promote girls' participation in STEM must extend beyond the classroom. The Government, schools, and Civil Society Organizations should implement community sensitization programmes aimed at challenging gender stereotypes and reshaping societal attitudes towards girls in STEM.

Enhance Monitoring, Evaluation, and Accountability Mechanisms

There is a need for robust monitoring and evaluation frameworks to assess the effectiveness of STEM initiatives at secondary school level. This includes tracking gender-disaggregated data on enrolment, participation, and performance, as well as ensuring accountability in the implementation of gender equity policies.

Ethical Approval

We obtained ethical clearance for the study from the University of Zambia Humanities and Social Sciences Research Ethics Committee (REF NO. HSSREC-2024-JAN-020) and the Lusaka District Education Board

(DEBs). Participants who were above 18 years provided written consent. Since the study was conducted in a boarding school, for participants below 18 years, written consent was obtained from the Head teacher's office and the school matrons, in full consultation with the parents, before any data collection activities were conducted.

This was because the parents were spread across Zambia, and the Head teacher's office and matrons had the legal basis to represent the parents in providing consent on their behalf. Assent was then obtained from participants below 18 years. Participants also verbally consented to having their interviews and FGDs audio-recorded. To maintain confidentiality, we anonymised the participants using participant identification numbers.

CRediT authorship contribution statement

Gracious Witola: Writing – review & editing, Writing – original draft, Visualization, Methodology (lead), Investigation, Formal analysis, Data curation, Conceptualization. Mukasami Monde Mwanangombe: Writing – review & editing, Methodology (supporting), Formal analysis (supporting). Natalie Mwila: Writing – review & editing, Formal analysis (supporting), Conceptualization (supporting). Brivery Siamabele: Writing – review & editing, Supervision (lead), Project administration, Methodology (lead).

Data Availability

The data is available upon request.

Conflicts of Interest

There was no conflict of interest whilst conducting this research.

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