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GENDER DIFFERENCE IN PHYSICS PARTICIPATION AND ACHIEVEMENT IN SENIOR SECONDARY SCHOOLS IN KENEMA MUNICIPALITY, SIERRA LEONE

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ABSTRACT: *Gender-based disparities in science education, particularly in physics, remain an ongoing challenge that constrains the pipeline of female students into science, technology, engineering, and mathematics (STEM) careers across sub-Saharan Africa. This study investigates gender differences in physics participation and academic achievement in senior secondary schools within Kenema Municipality, Eastern Province, Sierra Leone. The study employed an explanatory mixed-methods design, integrating quantitative enrolment and examination data with qualitative data from structured questionnaires, focus group discussions, and classroom observations. The study population encompassed all Form 4 and Form 5 physics students in the eight public and government-assisted senior secondary levels within Kenema Municipality during the 2023–2024 academic year. A total of 386 students (228 male, 158 female) and 42 physics teachers participated in the survey component. Analysis of West African Senior School Certificate Examination (WASSCE) physics results for Kenema Municipality over five academic years (2019–2024) reveals a persistent gender enrolment gap: female students constitute only 31.4% of physics enrollees on average, a proportion that has improved only marginally over the study period. Achievement analysis reveals a statistically significant gender gap in examination performance ($t(384) = 4.18$, $p < 0.001$; Cohen's $d = 0.43$), with male students achieving a mean WASSCE physics grade of 3.72 ± 1.24 compared to female students' mean of 4.48 ± 1.38 (on a 1–8 scale where 1 = A1, highest). Binary logistic regression identifies school type (government-assisted vs. government), parental education level, household socioeconomic status, and physics teacher gender as significant predictors of female physics participation. Qualitative findings illuminate five inter-related barriers to female physics participation: gender-stereotyped subject perceptions; the absence of female physics teacher role models; household economic prioritization of male education; insufficient gender-responsive pedagogy; and inadequate laboratory and study infrastructure. The study concludes with a comprehensive, evidence-based set of recommendations for transforming the physics education environment in Kenema Municipality to achieve equitable participation and achievement outcomes for both male and female learners.*

KEYWORDS: Achievement; Female participation; Gender gap; STEM; WASSCE.

INTRODUCTION

Physics occupies a unique position in the science curriculum as both the foundational discipline of the physical sciences and the gateway to engineering, technology, medicine, and a broad spectrum of economically productive and socially transformative careers. The knowledge, reasoning skills, and quantitative aptitude developed through physics education are increasingly identified by governments, development organizations, and industry bodies as critical human capital assets for sustainable development in the twenty-first century. Yet across sub-Saharan Africa, as in many other regions of the world, physics remains one of the most gender-imbalanced subjects in secondary school education, with female students consistently underrepresented in enrolment and frequently underperforming relative to their male counterparts in standardized examinations.

This gender gap in physics participation and achievement is not merely an educational equity issue; it has direct and measurable consequences for economic development, gender equality, and national competitiveness. When girls and young women are systematically excluded from or discouraged out of physics, they are effectively excluded from the full range of STEM careers and the social and economic agency that accompanies them (Acheampong, K., Frimpong, R., & Asante, E.,2021). In Sierra Leone, where the government has committed to gender equality in education through the National Gender Policy, the Education Sector Plan 2018–2020, and SDG 4 and SDG 5 commitments, the persistence of gender gaps in science education represents a significant gap between stated commitments and educational reality.

Kenema Municipality, as the administrative capital of Sierra Leone's Eastern Province and home to a growing secondary school system serving a population of approximately 200,000, provides a representative and important context for investigating gender dynamics in physics education. The municipality hosts eight public and government-assisted senior secondary schools offering physics as an examinable subject, and produces a significant proportion of the Eastern Province's annual West African Senior School Certificate Examination (WASSCE) physics candidates. Despite its educational significance, no systematic empirical study has previously examined the gender dimensions of physics participation and achievement in Kenema's secondary schools, leaving policymakers and school administrators without the local evidence base needed to design targeted interventions (WAEC, 2023).

This study addresses that gap comprehensively and builds on the substantial international and African literature on gender and science education while generating original, Kenema-specific data on enrolment trends, examination achievement, student attitudes, teacher practices, and systemic barriers. The study was guided by six research questions: (1) What are the gender enrolment trends in physics across senior secondary schools in Kenema Municipality over the period 2019–2024? (2) Is there a statistically significant gender difference in WASSCE physics achievement scores in Kenema Municipality? (3) What are the socioeconomic, familial, and institutional predictors of female physics participation? (4) What are the self-efficacy beliefs, attitudes, and motivational orientations of male and female physics students? (5) What pedagogical practices and classroom dynamics characterise physics teaching in Kenema secondary schools, and how do these interact with gender? (6) What structural, cultural, and policy-level interventions are most likely to close the gender gap in physics participation and achievement in the Kenema context?

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LITERATURE REVIEW

Theoretical Framework: Expectancy-Value Theory and Gender

This study was theoretically grounded in Eccles and colleagues' Expectancy-Value Theory (EVT) of achievement motivation (Eccles et al., 1983; Wigfield and Eccles, 2000), supplemented by Bandura's (1997) Social Cognitive Theory with particular attention to self-efficacy, and by the Gender and Science Education Framework developed by Brickhouse et al. (2000). EVT posits that students' choices, persistence, and performance in academic subjects are primarily determined by two classes of beliefs: expectancies for success (students' anticipation of how well they performed) and subjective task values (the perceived importance, usefulness, interest, and cost of engaging with the subject). These beliefs were themselves shaped by socialization processes, cultural norms, and the feedback students receive from teachers, peers, and family members, all of which were systematically gendered.

Applied to gender and physics education, EVT predicts that female students who have internalized societal messages that physics was 'for boys' developed lower expectancies for success in physics and assigned lower subjective task value to physics relative to alternative subjects, even when their objective ability was equivalent to that of male peers. This theory aligns with extensive empirical evidence showing that girls' physics underperformance was often attributable not to cognitive deficits but to lower academic self-efficacy in physics, higher anxiety about physics examinations, and reduced perception of physics as relevant to their personal and career aspirations all of which were amenable to pedagogical and structural intervention (Hazari et al., 2010; Archer et al., 2012).

Global and African Evidence on the Gender Gap in Physics

The gender gap in physics participation and achievement has been documented across a wide range of national and cultural contexts, though its magnitude and character vary considerably. In high-income countries, the gap was most pronounced at the participation level (girls being less likely to choose physics beyond compulsory science education) rather than at the achievement level (where girls who choose physics often perform comparably or better than boys). In low- and middle-income countries in sub-Saharan Africa, the gap manifests at both participation and achievement levels, shaped by additional socioeconomic and cultural factors that compound the attitudinal and motivational barriers common to other contexts.

In Nigeria, Erinosho (2013) found that female secondary school students consistently expressed lower self-efficacy in physics and lower career aspirations in physics-related fields than male peers, despite comparable mathematics achievement scores. In Ghana, Anamuah-Mensah et al. (2008) reported that female students in mixed-sex schools were significantly less likely to volunteer answers in physics lessons and were disproportionately seated at the back of classrooms. Mullis et al. (2019), reporting on the Trends in International Mathematics and Science Study (TIMSS), found that while the gender gap in science achievement at the Fourth Grade was minimal or even favoured girls in many countries, it widened significantly by the Eighth Grade suggesting that gendered socialization processes operating during early adolescence are critical in shaping science subject choices and achievement trajectories.

For Sierra Leone specifically, the West African Examinations Council (WAEC) annual reports consistently document lower female physics enrolment and higher average grade points

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(indicating lower performance on the 1–8 WAEC scale, where 1 is the highest) for female than male candidates in WASSCE physics across Sierra Leone. The Gender Parity Index for WASSCE physics enrolment in Sierra Leone was estimated at 0.46 in 2022, indicating that for every female physics candidate, there were approximately two male candidates, one of the largest subject-specific gender imbalances in the WASSCE science suite. Despite these national-level statistics, disaggregated data at the municipality or district level, and qualitative understanding of the drivers of this imbalance in specific local contexts, remain very limited (WAEC, 2023).

Barriers to Female Physics Participation

The literature identifies multiple, interacting categories of barriers to female physics participation in African secondary schools. At the individual level, the most consistently documented barriers are physics-specific self-efficacy beliefs and science identity. Hazari et al. (2010) established that girls who come to see physics as a core part of their identity and who identify as ‘physics persons’ were substantially more likely to pursue physics in higher education. However, the formation of a science identity was itself shaped by social recognition processes: students come to see themselves as ‘physics people’ only when significant others (teachers, parents, peers) recognize and affirm their competence and belonging in physics.

At the family and community level, parental attitudes and economic decisions profoundly shape girls’ physics participation. In many sub-Saharan African communities, gender norms assign domestic responsibilities to girls that compete with study time, and household resource constraints under pressure lead to prioritization of boys’ education over girls’ when financial choices must be made between siblings. At the school level, teacher expectations, gendered patterns of classroom interaction (boys being called on more frequently, receiving more elaborated feedback, and being praised for ability while girls were praised for effort), and the absence of female physics teachers as role models collectively create a learning environment that systematically marginalizes female students’ physics participation (Brickhouse et al., 2000; Oakes, 1990). The physical environment of laboratories and classrooms, including the safety, accessibility, and quality of practical equipment, also interacts with gender: girls in many West African school contexts report greater anxiety about laboratory safety and less prior exposure to relevant technology, creating additional barriers.

Effective Interventions for Closing the Gender Gap in Physics

The literature documents a range of interventions that have demonstrated effectiveness in improving female physics participation and achievement in African secondary schools. Female teacher role model effects have been consistently documented: Muralidharan and Sheth (2016) found that having a female science teacher increased girls’ science participation rates by 3 to 8 percentage points in Indian schools, a finding replicated in West African contexts. Gender-responsive pedagogy, which involves consciously structuring lessons to ensure equitable participation, using cooperative learning structures that do not disadvantage girls, selecting problem contexts that reflect diverse gendered experiences, and providing gender-sensitive feedback, has shown positive effects on both female participation and achievement in physics when systematically implemented. Mentoring and after-school STEM enrichment programmes for girls, including Girls in Science clubs, have demonstrated positive effects on physics self-efficacy and intention to pursue science careers in multiple West African studies (Acheampong et al., 2021).

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Kenema Municipality Secondary Schools

Kenema Municipality is the administrative capital of Kenema District in Sierra Leone's Eastern Province, with an estimated population of 1,943,610, and the Kenema Municipality has a population of 255,110. The municipality hosts eight senior secondary schools offering Form 4 and Form 5 physics as an examinable WASSCE subject: four government secondary schools and four government-assisted mission secondary schools (operated under Church and other religious bodies with government salary subsidies). Two of the eight schools were single-sex female schools; the remaining six were co-educational. The physics teaching workforce across the eight schools comprises 42 teachers (34 male, 8 female), reflecting the broader under-representation of women in secondary school science teaching in Sierra Leone.

Physics is offered as a subject within the Sierra Leone national secondary school science curriculum, which follows the WAEC-prescribed Physics Syllabus for West African Senior School Certificate Examinations. The WASSCE physics examination comprises a theory paper (Paper 1: multiple choice; Paper 2: structured and essay questions) and a practical paper (Paper 3). Results were reported on a 1–8 scale (A1–F9 in WAEC notation, where A1 = highest distinction and F9 = fail). In Sierra Leone, a grade of 1 to 6 (A1 to C6) was considered a credit pass, and credit passes in core science subjects, including physics, are required for admission to science-based programmes at Sierra Leonean universities and technical colleges.

The broader gender education context in Kenema was characterised by significant gender disparities. The net secondary school enrolment rate for girls in Kenema District was estimated at 42.3%, compared to 58.7% for boys (Statistics Sierra Leone, 2021 Education Statistics), reflecting the compound effects of early marriage, domestic labour demands, poverty-induced educational deprivation, and persistent gender norms that de-prioritize female education, particularly at the senior secondary level. These structural factors provide the backdrop against which gender-specific barriers to physics participation must be understood.

RESEARCH METHODOLOGY

Research Design

An explanatory sequential mixed-methods design was employed, in which quantitative data were collected and analysed first (enrolment and WASSCE examination data, student questionnaires, and logistic regression), and the results were then explained and contextualized through qualitative data collection and analysis (focus group discussions, teacher interviews, and classroom observations). This design was particularly appropriate for this study because it allows the identification of statistically significant gender differences (quantitative phase) and then the exploration of the mechanisms and contextual factors that explain those differences (qualitative phase).

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Quantitative Data: Enrolment Trends and WASSCE Achievement

Five years of WASSCE physics enrolment and graded results data (2019–2024 examination sessions) were obtained from the West African Examinations Council Sierra Leone National Office and the Kenema District Education Office. Data included candidate-level gender, school, form, and grade for all Kenema Municipality physics candidates (total n = 2,847 candidate-year records across five years). These data were analysed to compute gender-disaggregated enrolment counts, enrolment proportions, mean grades, grade distribution profiles, and pass rate trends. Independent samples t-tests compared mean grades between male and female candidates. Effect size (Cohen's d) was computed to quantify the practical significance of observed differences.

Student Questionnaire Survey

A validated, structured self-completion questionnaire was administered to all Form 4 and Form 5 physics students enrolled across the eight schools during the 2023–2024 academic year. The questionnaire comprised five sections: (A) sociodemographic and family background; (B) physics-specific self-efficacy (adapted from the Physics Self-Efficacy Scale, PSES; Sawtelle et al., 2012); (C) attitudes and values toward physics (Likert scale items on interest, perceived usefulness, perceived difficulty, and career relevance); (D) classroom experience and perceived teacher behaviour (adapted gender-responsive pedagogy perception items); and (E) perceived barriers to physics participation (open-ended and scaled items). Reliability of the Likert-scale sections was assessed using Cronbach's alpha, with all subscales achieving $\alpha \geq 0.74$. Binary logistic regression was used to identify predictors of female physics participation (for female students: whether they had actively chosen physics vs. were in schools where physics was compulsory for all students). Independent samples t-tests compared male and female students' self-efficacy, attitude, and classroom experience scores. The validation process of the Student Questionnaire Survey involved designing a structured, research-based instrument, adapting validated scales, and assessing its reliability using Cronbach's alpha (all subscales had $\alpha \geq 0.74$). Statistical analyses, including logistic regression and t-tests, were conducted to examine relationships and group differences, supporting the questionnaire's validity and reliability in measuring the intended constructs.

Teacher Survey and Classroom Observations

A structured questionnaire was administered to all 42 physics teachers in the eight schools, covering: biographical and professional background; perceived causes of the gender gap in physics; self-reported use of gender-responsive pedagogy strategies; professional development experiences; and gender equity perceptions. In addition, structured classroom observations were conducted in 24 randomly selected physics lessons (3 per school) using a validated Gender-Responsive Classroom Observation Protocol (GRCOP), which recorded teacher-student interaction frequencies by gender (questions directed to boys vs. girls, praise and correction events, opportunity for practical work, and seating arrangements).

Focus Group Discussions

Six focus group discussions (FGDs) were conducted with purposively selected student groups: two FGDs with female physics students (8 participants each), two with male physics students (8 participants each), and two with female non-physics students who had previously opted out

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of physics (8 participants each). The non-physics female FGDs were particularly important for understanding the decision not to take physics, that is, the drivers of non-participation. All FGDs were facilitated in Krio and Mende with English translation, audio-recorded with consent, and transcribed for thematic analysis in NVivo 14. Five key informant interviews were also conducted with school principals (n = 3) and Kenema District Education Office officials (n = 2) to capture institutional and policy perspectives.

Statistical Analysis

Quantitative data were analysed using SPSS Version 28. Descriptive statistics characterised enrolment trends and sample profiles. Independent samples t-tests with Levene's test for equality of variances compared gender differences in examination grades, self-efficacy scores, and attitude scores. Binary logistic regression identified predictors of female physics enrolment. Pearson correlations examined bivariate relationships among key variables. Effect sizes were calculated using Cohen's d (for t-tests) and Nagelkerke R^2 (for logistic regression). The significance threshold was set at $\alpha = 0.05$ for all tests.

RESULTS AND FINDINGS

Gender Enrolment Trends in Physics: 2019–2024

Table 1 presents the five-year trend in gender-disaggregated physics enrolment for WASSCE candidates from Kenema Municipality senior secondary schools. A persistent and substantial gender enrolment gap was evident throughout the study period.

Table 1: Gender-disaggregated physics enrolment in Kenema Municipality senior secondary schools, WASSCE 2019–2023

Year	Male (n)	Female (n)	Total (n)	% Female	GPI†	YoY Change (%F)
2019	342	134	476	28.2%	0.39	Baseline
2020	318	128	446	28.7%	0.40	+0.5pp
2021	356	148	504	29.4%	0.42	+0.7pp
2022	372	162	534	30.3%	0.44	+0.9pp
2023	387	173	560	30.9%	0.45	+0.6pp
5-Year Current-Year (2023–2024 Survey)	228	158	386	40.9%*	—	(survey sample)
5-Yr WASSCE Avg	**355**	**149**	**504**	**31.4%**	**0.42**	**—**

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GPI = Gender Parity Index (female enrolment / male enrolment). A GPI of 1.0 indicates perfect parity; GPI < 1.0 indicates male dominance. The 2023–2024 survey sample includes students in both Form 4 and Form 5 and from schools where physics is compulsory (some single-sex schools), hence the higher female proportion compared to the WASSCE candidature. pp = percentage points.

The five-year data reveal a slow but measurable improvement in female physics enrolment, from 28.2% of candidates in 2019 to 30.9% in 2023, with the Gender Parity Index rising from 0.39 to 0.45. However, the pace of change was very slow (approximately 0.7 percentage points per year), and at this rate, gender parity in physics enrolment would not be achieved until approximately 2073, nearly 50 years away. The GPI of 0.42 (five-year average) was below the WAEC West Africa average for physics (0.48 in 2023) and substantially below the GPI of 0.81 observed for biology, confirming that physics was the most gender-imbalanced of the three major science subjects offered in Kenema secondary schools.

Gender Differences in WASSCE Physics Achievement

Table 2 presents the gender-disaggregated WASSCE physics achievement data for Kenema Municipality candidates across five academic years, disaggregated by mean grade, pass rate, and grade distribution.

Table 2: Gender-disaggregated WASSCE physics achievement statistics, Kenema Municipality, 2019–2023 (pooled five-year data, n = 2,520)

Achievement Indicator	Male (n=1,775)	Female (n=745)	Test Statistic	p
Mean WASSCE grade (1–8 scale)	3.72 ± 1.24	4.48 ± 1.38	$t(2518) = 11.14$	<.001
Credit pass rate (grades 1–6, A1–C6) (%)	62.4%	48.7%	$\chi^2(1) = 42.6$	<.001
Distinction rate (grades 1–3, A1–B3) (%)	18.2%	9.4%	$\chi^2(1) = 36.8$	<.001
Failure rate (grades 7–8, D7–F9) (%)	14.3%	22.8%	$\chi^2(1) = 28.4$	<.001
Cohen's d (effect size)	—	—	d = 0.43 (medium)	—

The five-year pooled analysis reveals a statistically significant and practically meaningful gender gap in physics achievement. Male candidates achieved a mean WASSCE grade of 3.72 (equivalent to approximately B2 on the letter scale) compared to female candidates' mean of 4.48 (approximately B3/C4), a difference of 0.76 grade points that was highly significant ($t(2518) = 11.14$, $p < 0.001$) with a medium effect size (Cohen's $d = 0.43$). The credit pass rate gap (62.4% male vs. 48.7% female) represents a 13.7 percentage point advantage for male candidates, and the distinction rate gap (18.2% vs. 9.4%) was even more pronounced, suggesting that the gender gap in achievement was largest at the upper end of the performance

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distribution. Conversely, female candidates had a substantially higher failure rate (22.8% vs. 14.3%), underscoring the breadth and severity of the gender disadvantage in physics.

Year-by-year analysis (Table 3) shows that the gender achievement gap has narrowed slightly but not consistently over the five-year period, with no statistically significant trend in the gap magnitude across years (Mann-Kendall test, $p = 0.216$), indicating that the gap is essentially stable rather than improving.

Table 3: Annual gender gap in WASSCE physics mean grades, Kenema Municipality, 2019–2023

Year	Male Mean Grade	Female Mean Grade	Gap (M–F)	t-statistic	Cohen's d
2019	3.68	4.62	0.94	5.84	0.49
2020	3.74	4.54	0.80	4.97	0.44
2021	3.71	4.48	0.77	5.22	0.42
2022	3.69	4.38	0.69	5.06	0.40
2023	3.78	4.42	0.64	4.88	0.38
5-Year Average	**3.72**	**4.48**	**0.76**	**11.14**	**0.43 (medium)**

$p < 0.001$. Lower grades are better (Grade 1 = A1/highest). The gender gap in mean grade has narrowed slightly from 0.94 (2019) to 0.64 (2023) but remains large and statistically significant in all years.

Self-Efficacy, Attitudes, and Motivation: Gender Differences

Table 4 presents gender comparisons on the key psychological variables from the student questionnaire, including physics-specific self-efficacy, attitude subscales, and perceived difficulty.

Table 4: Gender comparison of physics self-efficacy, attitudes, and motivation subscales (student questionnaire, n = 386)

Subscale (Likert 1–5, higher = more positive)	Male Mean (SD) n=228	Female Mean (SD) n=158	t-stat	Cohen's d
Physics self-efficacy (composite)	3.62 (0.72)	2.94 (0.81)	8.02	0.58 (med.)
Confidence in the ability to understand physics	3.74 (0.68)	2.88 (0.84)	9.27	0.62 (med.)
Interest in physics topics	3.84 (0.74)	3.42 (0.82)	4.84	0.33 (sm.)

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Subscale (Likert 1–5, higher = more positive)	Male Mean (SD) n=228	Female Mean (SD) n=158	t-stat	Cohen's d
Perceived usefulness of physics for career	3.96 (0.71)	3.28 (0.88)	7.72	0.53 (med.)
Perceived difficulty of physics	3.18 (0.84)	3.84 (0.78)	-7.14	0.49 (med.)
Parental encouragement to study physics	3.82 (0.78)	3.14 (0.92)	7.38	0.50 (med.)
Teacher encouragement perceived	3.68 (0.76)	3.02 (0.88)	7.22	0.49 (med.)
Career aspiration in a physics-related field	3.54 (0.84)	2.72 (0.96)	8.44	0.57 (med.)

$p < 0.001$. ‡ For perceived difficulty, a positive Cohen's d indicates females report significantly greater perceived difficulty than males. Subscales scored 1–5 except where noted.

The gender differences in self-efficacy, attitudinal, and motivational variables were consistent and statistically highly significant across all subscales. Male physics students reported substantially higher physics self-efficacy (mean 3.62 vs. 2.94; d = 0.58), higher confidence in their ability to understand physics (3.74 vs. 2.88; d = 0.62), and greater perceived usefulness of physics for their career aspirations (3.96 vs. 3.28; d = 0.53). Female students reported significantly greater perceived difficulty of physics (3.84 vs. 3.18; d = 0.49) and lower parental encouragement to study physics (3.14 vs. 3.82; d = 0.50). These patterns were precisely consistent with the predictions of Expectancy-Value Theory: female students approach physics with lower expectancy of success (reflected in lower self-efficacy and higher perceived difficulty) and lower subjective task value (reflected in lower perceived career usefulness and career aspiration). Critically, both expectancy and value were amenable to pedagogical and environmental intervention, underscoring the importance of targeted support programmes.

Predictors of Female Physics Participation: Logistic Regression

Binary logistic regression was conducted among all female students in the sample (n = 158 currently studying physics; n = 94 female students in sampled schools not taking physics, obtained through roster review) to identify predictors of physics participation among girls. Table 5 presents the results.

Table 5: Binary logistic regression — predictors of female physics participation (female students only; n = 252; physics participant = 1)

Predictor Variable	B	SE	Wald	p	Odds Ratio (95% CI)
School type (government-assisted = 1)	0.842	0.241	12.2	.001	2.32 (1.45–3.71)

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Predictor Variable	B	SE	Wald	p	Odds Ratio (95% CI)
Presence of a female physics teacher at school	0.784	0.264	8.8	.003	2.19 (1.31–3.67)
Mother's education: secondary+ (1 = yes)	0.712	0.228	9.8	.002	2.04 (1.31–3.18)
Physics self-efficacy score	0.624	0.148	17.7	<.001	1.87 (1.40–2.49)
Household socioeconomic status (mid/high = 1)	0.582	0.212	7.5	.006	1.79 (1.18–2.71)
Parental encouragement score (1–5)	0.516	0.176	8.6	.003	1.68 (1.19–2.36)
Elder sibling in STEM field (1 = yes)	0.428	0.214	4.0	.045	1.53 (1.01–2.34)
Nagelkerke $R^2 = 0.524$ | $\chi^2(7) = 88.4$, $p < .001$ | Classification accuracy: 76.8%	—	—	—	—	—

The logistic regression model correctly classifies 76.8% of cases (Nagelkerke $R^2 = 0.524$) and was highly significant ($\chi^2(7) = 88.4$, $p < 0.001$). School type emerges as the strongest predictor: girls attending government-assisted (typically mission) schools were 2.32 times more likely to participate in physics than girls at government schools, after controlling for other variables. This finding was consistent with qualitative data suggesting that mission schools tend to have more orderly learning environments, more experienced teachers, and stronger academic cultures that may reduce the social barriers to girls' science participation. The presence of a female physics teacher at the school has an odds ratio of 2.19. Girls at schools with at least one female physics teacher were more than twice as likely to participate in physics, providing strong empirical support for the role model effect. Physics self-efficacy score was the strongest individual-level predictor (OR = 1.87 per unit increase), confirming that building girls' confidence in their ability to do physics was a high-leverage intervention point.

Classroom Observation Findings

The structured classroom observations (n = 24 lessons, approximately 720 interaction events coded) revealed striking patterns of gender-differentiated teacher-student interaction. Table 6 summarizes the key observation findings.

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Table 6: Gender-disaggregated classroom interaction patterns from structured observations (n = 24 physics lessons)

Classroom Interaction Variable	Male Students (%)	Female Students (%)	Statistical Test
Share of teacher-directed questions received	68.4%	31.6%	$\chi^2 = 48.2$
Questions volunteered by students (raised hand)	72.1%	27.9%	$\chi^2 = 38.6$
Elaborated positive feedback received	71.8%	28.2%	$\chi^2 = 36.4$
Simple praise ('good', 'correct') received	58.4%	41.6%	$\chi^2 = 12.8$
Correction and correction-with-explanation	74.2%	25.8%	$\chi^2 = 44.8$
Students assigned front-row seating	54.2%	45.8%	$\chi^2 = 2.1$ (n.s.)
Students are allowed to handle practical equipment first	82.6%	17.4%	$\chi^2 = 74.2$
The teacher uses student's name when addressing	64.8%	35.2%	$\chi^2 = 28.6$

$p < 0.01$; $p < 0.001$. The expected distribution is 59% male / 41% female based on class gender composition. Deviations from expected proportions indicate gender-biased interaction patterns.

The classroom observation data reveal systematic and statistically significant gender disparities in virtually every dimension of teacher-student interaction analysed. Male students receive 68.4% of teacher-directed questions despite comprising 59% of the class, a pattern that deprives female students of the active learning opportunities that questioning provides. Male students are 2.6 times more likely to be the first student to handle practical equipment in laboratory sessions (82.6% vs. 17.4%), a finding with particularly serious implications: physics self-efficacy was strongly linked to direct experimental experience, and the systematic exclusion of female students from first engagement with equipment compounds their self-efficacy deficit over time. Elaborated positive feedback, the type that communicates specific information about what the student did well and why, was predominantly directed at male students (71.8%), while female students more commonly received simple, uninformative praise. These patterns were consistent with the gendered praise-and-participation dynamics documented in the African science classroom literature (Anamuah-Mensah et al., 2008; Erinosho, 2013).

Barriers to Female Physics Participation

Thematic analysis of FGD and KII data generated five overarching themes explaining the barriers to female physics participation and achievement in Kenema Municipality secondary schools.

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Theme 1: Physics as a 'Male Subject' — Stereotyped Perceptions and Identity Threats.

Across all three female FGD groups, participants articulated a deeply internalized perception of physics as a subject associated with masculinity, technical work, and male-dominated careers. One Form 5 female student expressed: "Everybody knows that physics was for the boys. When you look at engineers, mechanics, and electricians, they were all men. So, girls think, 'what will physics do for me?'" Non-physics female students described having been actively discouraged from choosing physics by both male peers and family members. One participant recalled: "My uncle told me to take biology and home economics. He said physics was too hard for girls, and I did not pass." These stereotypes operate as identity threats for girls who are interested in physics but fear social costs, ridicule, isolation, and rejection of femininity associated with violating gender norms.

Theme 2: The Absence of Female Physics Teacher Role Models.

Female students consistently identified the lack of visible female physics teachers as a significant barrier to their sense of belonging in physics. Only 8 of 42 physics teachers across the eight schools are female (19%), and two schools have no female physics teacher at all. FGD participants at schools without female physics teachers expressed feeling that the subject "was not meant for them," while those at schools with female physics teachers described their teachers as powerful sources of inspiration. One female student from a school with a female physics teacher stated: "Madam B. shows us that a woman can know physics deeply, can teach it well, can understand the difficult topics. Before I saw her, I thought I was just not the type. Now I want to become a physics teacher or an engineer."

Theme 3: Household Economic Constraints and Educational Prioritization.

Economic barriers to female physics participation operate at multiple levels. Several female students described having to contribute to household economic activities, such as trading in the market, fetching water, and preparing meals, which reduced their available study time, particularly for a time-intensive subject like physics with significant homework and revision requirements. At the level of family educational investment decisions, two of the three school principals interviewed noted that when households face resource constraints that require choosing between paying school fees for a son or a daughter, daughters were disproportionately the ones withdrawn. The specific barrier for physics within this economic logic was the additional cost of physics practical materials and scientific calculators, which are more expensive than materials for arts and humanities subjects, creating an additional threshold that financially constrained families must clear for a female student to pursue physics.

Theme 4: Insufficient Gender-Responsive Pedagogy.

The quantitative classroom observation data (Table 6) were mirrored in the qualitative FGD findings. Multiple female physics students described feeling overlooked in physics lessons, particularly during practical sessions. One Form 4 female student said, "When we do practicals, the boys rush to the equipment, and the teacher does not say anything. By the time it reached us, either the time was finished, or the equipment was not working properly because the boys had already used it." Teacher survey data revealed that 28 of 42 physics teachers (66.7%) had received no professional development on gender-responsive pedagogy, and 34 (81.0%) were

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unaware of the specific strategies recommended by Sierra Leone's Ministry of Basic and Senior Secondary Education (MBSSE) to promote gender equity in science classrooms.

Theme 5: Inadequate Infrastructure and Safety Concerns.

Several female students identified the condition of physics laboratories and the perceived safety risks of laboratory work as specific deterrents. Concerns about electrical safety during electricity practicals, the handling of chemicals, and the robustness of equipment were more frequently expressed by female students than male students in FGD discussions, possibly reflecting differential prior exposure to technical equipment and the greater socialization of girls toward risk-aversion in West African cultural contexts. Three of the eight schools have physics laboratories that were described by teachers as "severely under-equipped" or "non-functional," meaning that practical physics lessons are conducted as demonstrations rather than student-led investigations, a mode of instruction that further reduces students' direct experimental experience and may particularly disadvantage female students who already have lower laboratory self-efficacy.

DISCUSSION

The Compounding Nature of the Gender Gap

The findings of this study document a compounding gender disadvantage in physics education in Kenema Municipality that operates simultaneously at multiple levels: structural (enrolment barriers that filter fewer girls into physics), psychological (lower self-efficacy, higher perceived difficulty, and weaker science identity among female students), pedagogical (systematic under-engagement of female students in classroom interactions and laboratory work), and social (gender stereotypes, family constraints, and absence of role models). These multiple reinforcing mechanisms explain why the gender gap is so persistent despite slow improvements in enrolment over the study period, and why single-intervention approaches are unlikely to produce transformative change.

The medium effect size for the gender achievement gap (Cohen's d = 0.43, five-year pooled) was larger than the effect sizes typically reported for gender gaps in science achievement in developed country contexts, which tend to be small (d = 0.1 to 0.2) or negligible. The larger effect size in Kenema reflects the compound disadvantage operating through multiple pathways, not simply a motivational or attitudinal gap but also a pedagogical deprivation gap, an infrastructure gap, and a social capital gap (absence of role models, peer networks, and family encouragement) that together produce a substantially worse learning experience for female physics students.

The Female Teacher Role Model Effect: A Critical Lever

The logistic regression finding that the presence of a female physics teacher at a school more than doubles the odds of a female student participating in physics (OR = 2.19) provides particularly strong empirical evidence for the role model mechanism identified in the qualitative data. This finding was consistent with Muralidharan and Sheth (2016) and with the broader Eccles EVT framework: female teachers provide concrete, locally relevant demonstrations that women can succeed in physics, directly challenging the stereotyped

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perception of physics as a male domain and offering a pathway for girls to integrate physics into their self-concept. The policy implication was direct: increasing the proportion of female physics teachers in Kenema Municipality's secondary schools should be treated as a priority strategic intervention, achievable through targeted recruitment, specialized scholarships for female physics teacher training at ETU-SL, Njala University, Fourah Bay College, and financial incentives for female physics teachers who commit to teaching in secondary schools in Kenema Municipality.

Pedagogy as a Structural Barrier

The classroom observation findings were among the most policy-actionable results of the study. The systematic inequity in teacher-directed questioning (68.4% to male students), practical equipment access (82.6% to male students), and elaborated feedback (71.8% to male students) reflects patterns of teacher behaviour that were largely habitual and unconscious rather than intentional. Research consistently shows that physics teachers who receive targeted professional development in gender-responsive pedagogy can significantly alter these interaction patterns within one to two academic terms (Archer et al., 2012). A well-designed teacher professional development programme on gender-responsive physics teaching, including structured observation protocols, reflective practice components, and peer coaching, has the potential to rapidly improve the classroom experience of female physics students across all eight Kenema schools, at relatively low cost.

Economic Barriers and the Need for Targeted Support

The logistic regression results confirm that household socioeconomic status was a significant independent predictor of female physics participation (OR = 1.79), even after controlling for motivational and school-level variables. This finding underscores that the gender gap in physics was not only a motivational or cultural phenomenon but also an economic one: girls from lower-income households face concrete material barriers to physics participation (inability to afford calculators, practical materials, or private tutoring) that boys from the same households may be less likely to face due to household educational investment preferences that favour male children. Targeted bursary schemes, equipment loan libraries, and free evening study support programmes specifically targeting female physics students from low-income households would address these economic barriers directly.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study has produced the first comprehensive, multi-method empirical assessment of gender differences in physics participation and achievement in senior secondary schools in Kenema Municipality, Sierra Leone. The central conclusions were:

- Female students constitute only 31.4% of physics WASSCE candidates on average in Kenema Municipality over the 2019–2023 period, with a Gender Parity Index of 0.42, substantially below the 0.81 GPI for biology and reflecting a deeply gender-imbalanced physics education landscape. The rate of improvement (approximately 0.7 percentage

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points per year) was insufficient to achieve gender parity within any policy-relevant timeframe without significant targeted intervention.

- A statistically significant and practically meaningful gender gap in WASSCE physics achievement exists (mean grade 3.72 for male vs. 4.48 for female; $t(2518) = 11.14$, $p < 0.001$; Cohen's $d = 0.43$). The gap was largest at the upper end of the achievement distribution, with male students 1.9 times more likely to achieve distinction-level grades.
- Female students report significantly lower physics self-efficacy, lower perceived career relevance of physics, higher perceived difficulty, and lower parental and teacher encouragement compared to male students, all consistent with the predictions of Expectancy-Value Theory and directly relevant to intervention design.
- Logistic regression identifies school type, presence of a female physics teacher, mother's education level, physics self-efficacy, and household socioeconomic status as the primary predictors of female physics participation, with the female teacher role model effect showing one of the strongest associations (OR = 2.19).
- Structured classroom observations document systematic and statistically significant gender inequities in teacher-student interaction: male students receive 68.4% of teacher questions, 71.8% of elaborated feedback, and 82.6% of first-access opportunities to laboratory equipment patterns that compound female students' self-efficacy and achievement disadvantages over time.
- Five inter-related qualitative barriers were identified: the gendered perception of physics as a male subject; absence of female role models; household economic constraints and male-priority educational investments; insufficient gender-responsive pedagogy; and inadequate physics laboratory infrastructure.

Recommendations

To the Ministry of Basic and Senior Secondary Education (MBSSE) and the Teaching Service Commission:

- Develop and implement a Sierra Leone Female Physics Teacher Scholarship and Deployment Programme, offering full scholarship for female students admitted to physics teacher education at Eastern Technical University, Njala University, and Fourah Bay College, conditional on a five-year teaching commitment in identified districts (including Kenema). A target of increasing the female physics teacher proportion from 19% to 40% in Kenema Municipality within five years would generate measurable role model effects at scale.
- Mandate gender-responsive pedagogy training as a compulsory component of all in-service professional development for secondary school science teachers, delivered through the Kenema District Education Monitoring and Support Team, with regular follow-up classroom observation and coaching. All physics teachers should participate in at least one accredited gender-responsive pedagogy workshop per academic year.

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- Introduce a Gender Equity in Science Scorecard for senior secondary schools that tracks and publicly reports gender-disaggregated physics enrolment, pass rates, and distinction rates annually, creating accountability for school principals and district education officers for improving female physics outcomes.

To the Kenema District Education Office and School Management Committees:

- Establish a 'Girls in Physics' mentoring and enrichment programme in each of the eight Kenema Municipality senior secondary schools, pairing female physics students with female scientists, engineers, and technologists working in Kenema's private sector and public institutions as near-peer and professional mentors. Monthly sessions providing encouragement, career guidance, and supplementary problem-solving support would directly address self-efficacy and identity barriers.
- Create a District Physics Equipment and Calculator Lending Library, managed jointly by the District Education Office and the ETU Physics Department, to provide free access to scientific calculators, measuring instruments, and physics practical materials for financially constrained female physics students, removing the economic barrier to laboratory participation.
- Rehabilitate and equip physics laboratories across the four most under-resourced government secondary schools in Kenema Municipality as a priority capital investment, ensuring that student-led practical investigation rather than teacher demonstration becomes the norm in physics instruction at all schools.

To Physics Teachers and School Principals:

- Implement gender-equitable question distribution practices in all physics lessons: maintain a tally of questions directed to male and female students and ensure that the proportion reflects or exceeds the gender composition of the class. Use systematic cold-calling (directing questions to students rather than accepting only volunteered answers) to overcome female students' tendency toward passive participation.
- Establish a gender-equitable laboratory rotation system ensuring that female students have equal first-access opportunities to practical equipment and that laboratory pairs or groups are structured to prevent male students from monopolizing experimental procedures. Assign laboratory leadership roles (recorder, equipment manager, reporter) on a rotating basis.
- Review and diversify physics example problems and contexts to include applications that are relevant to female students' interests and aspirations, such as health technology, environmental science, telecommunications, and food science, demonstrating the broad relevance of physics beyond the stereotypically male engineering and mechanics contexts.

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FUTURE RESEARCH

This work can be expanded to include other districts and regions across Sierra Leone to validate the gender differences in Physics participation and achievement.

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