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School–Community Perceptions Shaping Girls' Participation in STEM Education: Empirical Evidence from Nyagatare District, Rwanda

Jean Paul Uzabakiriho, Gaspard Gaparayi, Irénée Ndayambaje & Dorothy Tukahabwa
University of Rwanda, Rwanda

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Abstract
Persistent gender disparities in Science, Technology, Engineering, and Mathematics (STEM) education continue to limit girls' full participation, particularly in rural and under-resourced contexts. In Rwanda's Nyagatare District, these inequities are amplified by deep-rooted socio-cultural norms, institutional stereotypes, and a lack of gender-responsive support systems. Although national enrollment of girls in basic education has improved, their transition and completion rates in upper secondary STEM pathways remain significantly lower, reflecting a broader pattern of gendered attrition. This study investigates the interrelationship between Gender Biases and Stereotypes (GBS), School–Community Perceptions (SCP), and their influence on Girls' Participation in STEM (GWP). It also evaluates the role of Evidence-Based Interventions (EBI) in challenging structural and normative barriers. Grounded in Critical Feminist Theory, Social Cognitive Theory, and Social Constructivist Theory, the study adopts a convergent mixed-methods approach. Quantitative data were collected from 431 students and teachers, while qualitative insights were drawn from 34 key informants, including school leaders, parents, and education officials. Findings reveal that both descriptive (e.g., "boys are better at STEM") and injunctive (e.g., "girls should pursue caregiving careers") norms shape aspirations and identity. Chi-square and Phi analyses confirmed gender as a significant factor in stereotype reinforcement. However, inclusive interventions—such as career counselling, community awareness, and visible female role models—help counteract these biases. The study proposes the Gender-Responsive STEM Equity Model (GRSEM) to guide transformative, inclusive STEM education reform in Rwanda and similar settings.

Introduction
Despite global commitments to equity, gender disparities in Science, Technology, Engineering, and Mathematics (STEM) persist, particularly in rural and low-resource settings where socio-cultural norms, structural inequities, and educational inequalities intersect to limit girls' participation (UNESCO, 2023; Wang & Degol, 2017). While Rwanda has made commendable progress in basic education enrollment for girls through inclusive policy frameworks, the gender gap in STEM remains entrenched beyond primary education (Murphy et al., 2022).

Recent national statistics show that girls' enrollment in lower secondary school increased marginally from 54.1% in 2020/21 to 54.6% in 2022/23, while boys still dominate upper secondary, TVET, and tertiary STEM tracks (NISR, 2023). In Nyagatare District, a rural region in Eastern Rwanda, this imbalance is even more pronounced: although 98% of girls complete primary school, only 57% transition to lower secondary, and fewer than 30% complete upper secondary STEM pathways (MINEDUC, 2023). Gendered enrollment patterns in TVET further reflect this divide, with girls concentrated in caregiving and agriculture, while boys dominate engineering and ICT (Nsabimana et al., 2021).

These disparities are driven less by ability and more by gendered expectations, early pregnancy, domestic labour, limited digital access, and institutional biases (Kabayiza et al., 2020). For example, only 9.7% of Rwandan females aged 15–24 are computer literate compared to 11.4% of males (NISR, 2023). Curriculum content, lack of female STEM role models, and insufficient gender-sensitive career guidance further alienate girls from STEM (Else-Quest et al., 2013; Blickenstaff, 2005).

This study investigates how Gender Biases and Stereotypes (GBS), shaped by School–Community Perceptions (SCP), influence Girls' Participation in STEM (GWP), and explores how Evidence-Based Interventions (EBI) can counter systemic barriers. Focusing on Nyagatare District, the research aims to propose actionable, contextually relevant strategies to foster equitable access and achievement in STEM for girls. Ultimately, this work contributes to advancing gender-responsive educational leadership and inclusive STEM transformation in Rwanda.

Literature Review

Gender stereotypes continue to function as a powerful barrier to girls' participation in STEM. Globally, STEM is often constructed as a masculine domain, privileging attributes like logic, independence, and competitiveness—traits traditionally associated with boys (Cheryan et al., 2017; UNESCO, 2021). These stereotypes manifest in two ways: descriptive norms, which shape who is perceived to belong in STEM, and injunctive norms, which dictate who should pursue it (Cialdini et al., 1991; Tankard & Paluck, 2016).

In rural Rwanda, these norms intersect with socio-cultural beliefs that prioritise girls' caregiving roles, discouraging their pursuit of science and technology. Within schools, biases are evident through unequal teacher expectations, limited support for girls in science clubs, and scarce leadership opportunities (Mumporeze & Prieler, 2017; UNICEF Rwanda, 2023). Girls are further discouraged by the lack of female role models, gender-insensitive learning materials, and unsupportive community narratives (Uwineza et al., 2020; Kayitesi et al., 2022).

These challenges are deeply systemic. Inequities are embedded within policy structures, school environments, and sociolinguistic norms that perpetuate exclusion. Addressing these requires a paradigm shift—from deficit-based approaches to transformative, inclusive practices that validate and empower girls' aspirations in STEM.

Theoretical Framework

This study employs a multi-theoretical lens to examine the dynamics influencing gender inequity in STEM education in Nyagatare. The integrated framework draws on Critical Feminist Theory, Social Cognitive Theory, and Social Constructivist Theory—each informing the conceptualisation and design of the Gender-Responsive STEM Equity Model (GRSEM).

Critical Feminist Theory

Critical Feminist Theory (hooks, 1984; Arnot & Phipps, 2021) critiques structural patriarchy and exposes how education systems reproduce male privilege, particularly in STEM. In Nyagatare, girls' marginalisation is visible in male-dominated science tracks, gender-biased counselling, and the invisibility of women in curricular content and school governance (Uworwabayeho & Nkengurutse, 2022). GRSEM uses this theory to challenge institutional hierarchies and frame gender equity as a transformational imperative.

Social Cognitive Theory

Bandura's Social Cognitive Theory (1997) posits that academic behaviour is shaped by self-efficacy, observational learning, and social reinforcement. Girls' STEM engagement increases when they believe in their competence and are supported by role models, affirming teachers, and inclusive school practices (Beede et al., 2011; Uwizeyimana et al., 2023). GRSEM applies these insights through EBI, such as mentorship, gender-responsive pedagogy, and personalised guidance.

Social Constructivist Theory

Vygotsky's Social Constructivist Theory (1978) argues that learning and identity formation occur through social interaction. In rural Rwanda, narratives that favour boys in science are often co-constructed within families, peer groups, and religious institutions (Tadesse et al., 2021). GRSEM integrates this framework by emphasising the importance of shifting School–Community Perceptions (SCP) through participatory dialogue and cultural responsiveness.

Conceptual Framework: The Gender-Responsive STEM Equity Model (GRSEM)

The Gender-Responsive STEM Equity Model (GRSEM) forms the analytical backbone of this study. Synthesising the three theoretical approaches above, GRSEM identifies four interrelated variables:

- Gender Biases and Stereotypes (GBS)
- School–Community Perceptions (SCP)
- Evidence-Based Interventions (EBI)
- Girls' Participation in STEM (GWP)

GRSEM views these variables as dynamically interconnected within a broader ecosystem of learning and socialisation. For example, shifting community attitudes can trigger teacher support, which in turn fosters girls' confidence and sustained participation. The model is both diagnostic—highlighting how exclusion is reproduced—and interventionist—offering practical entry points for change.

Aligned with Rwanda's national education goals and global frameworks like SDGs 4 (Quality Education) and 5 (Gender Equality), GRSEM (see Figure 1) serves as a strategic tool for policymakers, educators, and development partners seeking to promote gender-responsive reform in STEM education across rural and underserved communities.

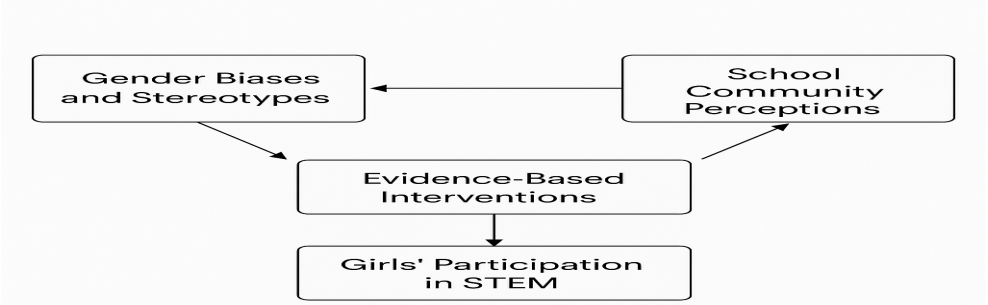

Figure 1. Gender-Responsive STEM Equity Model (GRSEM)

Methodology

Research Design

This study adopted an explanatory sequential mixed-methods design (Creswell & Plano Clark, 2017) to explore how gender biases and stereotypes (GBS)—moderated by school–community perceptions (SCP)—influence girls' participation in STEM (GWP) in Nyagatare District, Rwanda. A quantitative phase established statistical associations, followed by a qualitative phase that contextualised findings through stakeholder narratives. This approach allowed for triangulation and ensured depth, rigour, and integration across data sources. Critical Feminist Theory, Social Cognitive Theory, and Social Constructivist Theory guided the study.

Population and Sampling

The study targeted STEM-track students and teachers across Nyagatare's 14 sectors. From this population, 322 students (Senior 4–6 General Education and Levels 3–5 TVET) and 109 STEM teachers (math, biology, chemistry, physics, ICT) were selected using purposive sampling informed by power analysis, gender metrics, and sectoral diversity (Creswell, 2014).

Qualitative Stakeholder Selection

The qualitative phase engaged 34 informants: 12 headteachers, 11 School General assembly Committee (SGAC) members, ten Sector Education Inspectors (SEIs), and the District Education Officer (DEO). This article focuses on six purposively selected sectors—Kiyombe, Mukama, Nyagatare, Rwempasha, Tabagwe, Katabagemu—chosen for thematic richness, school typologies, and gender relevance in STEM. Complete data are detailed in the broader dissertation.

Inclusion and Exclusion Criteria

Participants actively involved in STEM education in Nyagatare District—including students (15+), STEM teachers, school leaders, SGAC members, and education officers—were purposively selected. Parental consent was obtained for minors. Those unaffiliated with STEM or outside the district were excluded to maintain contextual relevance and uphold ethical research standards.

Data Collection and Analysis

Quantitative data were collected using a validated 166-item questionnaire, pre-tested in Gatsibo District (Cronbach's α = .935). Data analysis in SPSS v21 included Chi-square tests, Phi coefficients, Spearman's rho, and binary logistic regression. The qualitative phase used semi-structured interviews conducted in Kinyarwanda and translated into English. Data were analysed using Braun and Clarke's (2006) thematic analysis, combining inductive and deductive coding.

Ethical Considerations and Rigour

Ethical approval was granted by the University of Rwanda–College of Education Research Ethics Committee. Additional permissions were obtained from district officials and school administrators. Participants gave informed consent, and confidentiality was strictly observed. Methodological rigour was ensured through pilot testing, triangulation, reliability checks, peer debriefing, and audit trails. Integration of mixed-methods provided a robust, evidence-informed analysis of gendered educational pathways in STEM.

Results

Gender disparities in Science, Technology, Engineering, and Mathematics (STEM) education in Nyagatare District reflect deep-rooted socio-cultural ideologies, patriarchal expectations, and institutional inequities. This section presents both quantitative and qualitative findings, structured around the study's conceptual lens—Critical Feminist Theory (hooks, 2000), Social Cognitive Theory (Bandura, 1997), and Social Constructivist Theory (Vygotsky, 1978)—and guided by the Gender-Responsive STEM Equity Model (GRSEM). The analysis is informed by descriptive and injunctive norms, domestic labour expectations, and predictive modelling, culminating in a theoretically grounded interpretation of how school–community perceptions (SCP) and evidence-based interventions (EBI) shape girls' and women's participation in STEM (GWP).

Descriptive Norms: Masculinisation of STEM

Descriptive norms capture socially shared beliefs regarding behaviours perceived as common or typical within specific contexts (Cialdini et al., 1991).

Table 1: Normative Beliefs on Gender and STEM Roles

No	Statement	Disagree (%)	Neutral (%)	Agree (%)
1	Caregiving is only for women	49.2	25.8	25
2	Only men earn income	47.8	23.4	28.8
3	Engineering suits males	40.1	17.9	42
4	Women are less interested in technology	36.5	21.5	42
5	Physics/mechanics are masculine	43.1	18.6	38.3
6	Women lack analytical ability	44.3	22.5	33.2
7	STEM requires physical strength	36.8	21.2	42
8	Girls uninterested in tinkering	39	20.6	40.4
9	Technology careers are male-dominated	42.7	15.7	41.6
10	Leadership in STEM is for men	41.6	16.8	41.6

Table 1 reveals entrenched gender perceptions in STEM, with over 40% endorsing male dominance in engineering, technology, and physics. Statements like "Engineering suits males" and "Women are less interested in technology" reflect STEM's masculinisation. Neutral responses (17–26%) suggest ambivalence, indicating passive acceptance of gender norms that are internalised early and reinforced through schooling and community narratives.

Injunctive Norms and Gender Authority

Injunctive norms—community-driven expectations about gender roles—profoundly shape girls' self-efficacy and future aspirations. As illustrated in *Figure* 2, many respondents upheld beliefs such as women requiring spousal permission for healthcare and men serving as sole financial decision-makers. These norms legitimise male dominance and constrain girls' autonomy, diminishing their sense of agency in academic and career pursuits. By reinforcing hierarchical gender roles, injunctive norms suppress the development of STEM identities among girls and perpetuate educational and societal inequities.

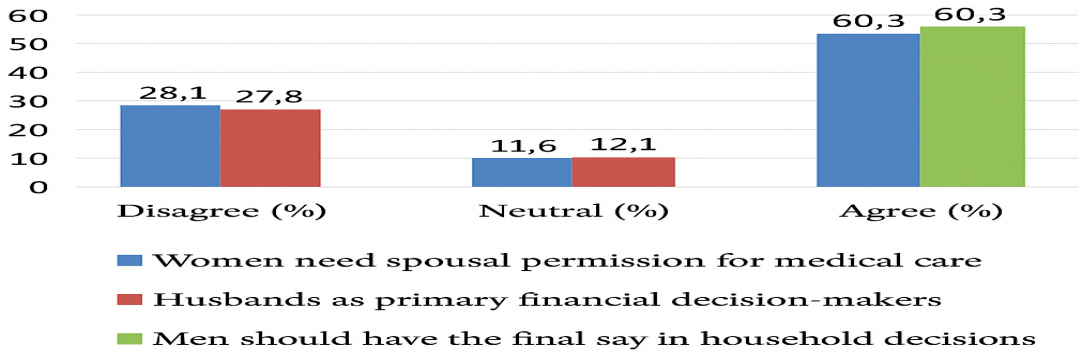

Figure 2: Injunctive Normative Beliefs on Gender Authority

Gendered Division of Labour: Time Poverty and STEM Exclusion

Gendered domestic roles structurally constrain girls' engagement in STEM by creating chronic time poverty. As illustrated in Figure 3, caregiving norms limit study time, extracurricular participation, and cognitive bandwidth, weakening STEM identity and academic persistence. These expectations, especially in rural settings, erode self-concept and long-term aspirations, reinforcing gender disparities in science and mathematics education.

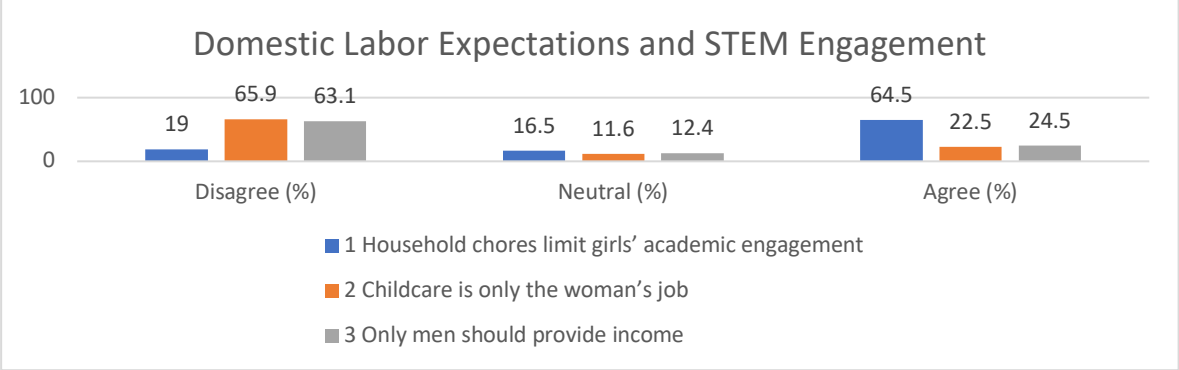

Figure 3: Domestic labour expectations and STEM Engagement

Predictive Modelling of Gender and Stereotype Endorsement

Chi-Square Analysis

To examine gendered patterns in STEM-related stereotype endorsement, a Chi-square test of independence was applied to key belief statements. As shown in Table 2, statistically significant associations emerged between gender and support for three stereotypes. Male participants were more likely to agree that "Boys are naturally better at STEM" ($\chi^2 = 19.87$, $p < .001$, $\varphi = 0.215$), "Girls are uninterested in tinkering" ($\chi^2 = 11.77$, $p = .003$, $\varphi = 0.167$), and "Engineering suits males" ($\chi^2 = 16.42$, $p = .001$, $\varphi = 0.196$), reinforcing normative gender biases in STEM identity formation.

Table 2: Associations Between Gender and Stereotype Endorsement (n = 431, df = 2)

Statement	χ^2	p-value	Phi
Boys are naturally better at STEM	19.87	< .001	0.215
Girls uninterested in tinkering	11.77	0.003	0.167
Engineering suits males	16.42	0.001	0.196

Chi-square analysis revealed that male respondents significantly endorsed STEM gender stereotypes, with moderate effect sizes ($\varphi = 0.167–0.215$), underscoring the social entrenchment of gendered beliefs and the urgent need for transformative, equity-driven educational reforms.

Logistic Regression Analysis

To complement the Chi-square analysis, a binary logistic regression identified key predictors of STEM stereotype endorsement. Gender (male) significantly increased the likelihood of endorsement (Exp(B) = 2.58, $p < .001$), while parental encouragement (Exp(B) = 0.668, $p = .004$) and exposure to inclusive role models (Exp(B) = 0.723, $p = .033$) were protective factors. Although career counselling showed a non-significant trend ($p = .09$), its potential warrants further exploration. These findings underscore how socio-cultural and educational influences shape gendered beliefs in STEM, reinforcing the need for targeted interventions that promote representation, family engagement, and inclusive school climates.

Table 3: Logistic Regression Predictors of Stereotype Endorsement (n = 431)

Predictor	Exp(B)	95% CI	p-value
Gender (Male)	2.58	[1.78, 3.74]	< .001
Parental Encouragement	0.668	[0.50, 0.88]	0.004
Inclusive Role Models	0.723	[0.54, 0.97]	0.033
Career Counselling	0.801	[0.62, 1.04]	0.09

Model fit indicators (Nagelkerke $R^2 = 0.132$; Hosmer-Lemeshow $\chi^2 = 5.18$, $p = 0.74$) confirm the model's adequacy. Gender (male) significantly increased the likelihood of stereotype endorsement (OR = 2.58, $p < .001$), while parental encouragement and exposure to inclusive role models were both significant protective factors. Although career counselling showed a marginal effect, its potential warrants further exploration in comprehensive gender-responsiveness programming. These results empirically validate the transformative potential of targeted interventions at the family and school levels.

Integration of Qualitative Findings: Gendered Barriers to Girls' Participation in STEM

Drawing from rich narratives of students, teachers, school leaders, and community stakeholders in Nyagatare District, this section interrogates the multi-layered socio-cultural and institutional dynamics constraining girls' access, retention, and success in STEM education. The analysis unearthed six mutually reinforcing barriers, mapped onto the core pillars of the Gender-Responsive STEM Equity Model (GRSEM)—Gender Biases and Stereotypes (GBS), School–Community Perceptions (SCP), Evidence-Based Interventions (EBI), and Girls' STEM Participation (GWP).

These findings reflect and align with the study's guiding theoretical lens, which combines critical insights on structural inequality, social learning, and the co-construction of gender roles, anchoring the thematic interpretations in a coherent analytical frame.

STEM as a Masculinised Terrain

Causal Pathway: GBS → GWP

STEM fields, particularly physics, engineering, and construction, are widely perceived as masculine spaces. Girls who pursue these disciplines face symbolic sanctions and are seen as transgressing gender norms. Such stigma delegitimises their interests and reinforces exclusion (KII-DEDU001; KII-SEI002; KII-SECM2005). "Girls in engineering are seen as breaking rules… like they're acting like boys." — *KII-SECM2005*.

Interpretation: This reflects the normative gendering of STEM within power-laden discourses and mirrors broader structures of exclusion, as captured within the study's critical and socio-constructive paradigm.

Internalised Doubt and Eroded Self-Efficacy

Causal Pathway: GBS → Low Self-Efficacy → GWP

Consistent exposure to gendered messaging from peers, parents, and educators undermines girls' belief in their capabilities, especially in mathematics and science. This leads to avoidance behaviour and loss of

interest in STEM (KII-SEI003; KII-DEDU001). "I was afraid to fail in science; they say girls are not good at it." — *KII-STU007*

Interpretation: These findings correspond to self-efficacy mechanisms shaped by socially constructed expectations, reinforcing gender disparities in achievement and choice.

Cultural Sanctions and Femininity Risks
Causal Pathway: GBS × SCP → GWP

Girls in STEM are often labelled *igishegabo* (tomboy), suggesting a loss of femininity and reduced marriageability. These cultural sanctions deter girls from aligning themselves with STEM identities (KII-HT003; KII-STU010; KII-SEI002). "They say if you study physics, you will not get a husband." — *KII-STU010.*

Interpretation: This reflects a culturally constructed gender dichotomy that penalises STEM aspiration, perpetuating stereotypes and gender-role conformity within rural education ecosystems.

Gendered Tracking and Occupational Segregation

Causal Pathway: SCP × GBS → Inadequate EBI → GWP

Girls are disproportionately channelled into non-technical academic tracks based on assumptions about their interests and capacities. In TVET, this tracking leads to their overrepresentation in hospitality and tailoring, while boys dominate ICT and engineering (KII-DEDU001; KII-HT010; KII-SECM2005). "In our school, boys go to electricity; girls choose tailoring." — *KII-HT010.*

Interpretation: Such institutionalised patterns of segregation confirm the intersection of cultural bias and systemic inertia, illustrating how entrenched social constructs shape educational and occupational futures.

Institutional Deficits in Mentorship and Retention

Causal Pathway: Lack of EBI → Drop in GWP
There is a notable absence of gender-responsive interventions, including mentorship, resilience coaching, and female STEM role models. Without structured support, girls often withdraw from STEM subjects after experiencing academic difficulty (KII-HT001; KII-SEI002). "When girls fail once in science, they shift to another subject—there's no support to keep them going." — *KII-HT001.*

Interpretation: This gap reflects institutional inertia and a missed opportunity for modelling and reinforcing persistence, especially in contexts where identity and capability are socially negotiated.

Intergenerational Transmission of Bias
Causal Pathway: GBS → Long-Term Impact on GWP
Gendered assumptions about science and technology are passed down across generations, becoming normalised within familial and community discourse from early childhood (KII-HT006). "Most girls grow up hearing that science is for boys—it becomes their truth." — *KII-HT006.*

Interpretation: These belief systems are socially inherited and reproduced through discourse, reinforcing early gendered pathways and shaping future decisions.

Toward Gender-Responsive Reform

Collectively, the six barriers affirm that girls' exclusion from STEM is structurally produced, not inherently determined. Addressing this requires coordinated, multi-tiered interventions that reimagine both policy and practice. Key reform priorities include:

- Decolonising curricula to eliminate stereotype-laden content
- Training educators and leaders in gender-responsive pedagogy
- Facilitating school–community dialogues to shift local perceptions
- Building mentorship ecosystems with visible female role models
- Establishing psychosocial and academic support tailored to girls in STEM

These priorities align with GRSEM domains and provide a scaffold for sustained, evidence-informed transformation.

Interpretive Synthesis and Action Framework

Thematic analysis of qualitative data affirms the coherence and practical relevance of the Gender-Responsive STEM Equity Model (GRSEM). Figure 5 distils the core strategic entry points for transforming gender dynamics in STEM education. These leverage points—derived from the lived experiences of students, educators, and community stakeholders—serve as actionable pathways for targeted policy reform, institutional innovation, and sustained community mobilisation toward gender equity.

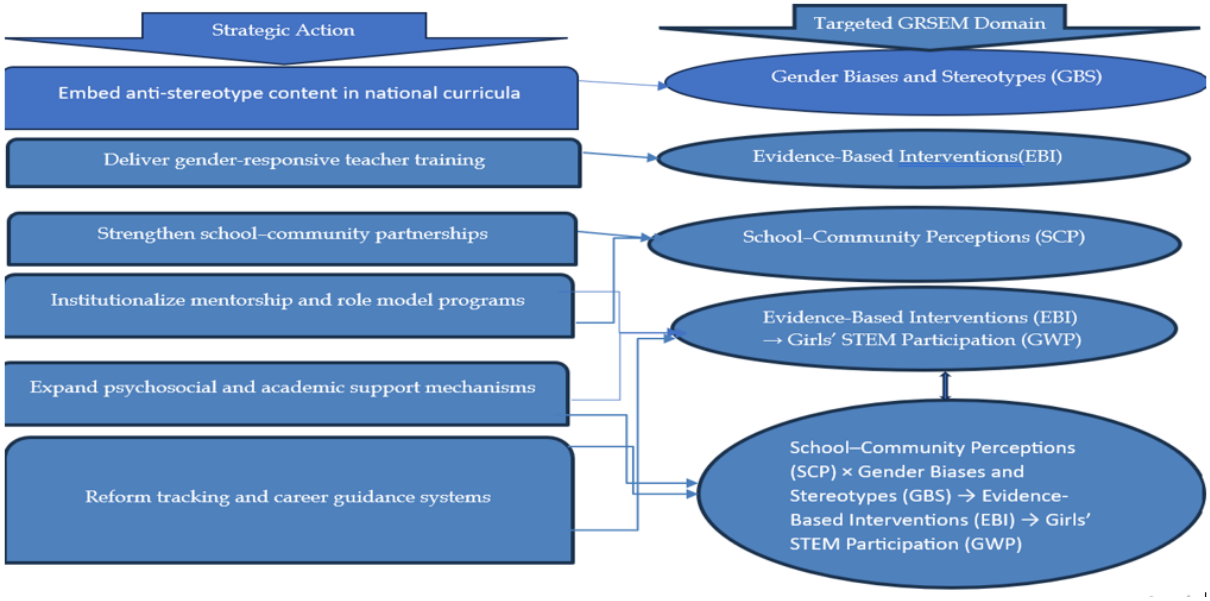

Figure 4: Strategic Actions Driving Gender-Responsive STEM Equity in Education

These strategies offer scalable and contextually grounded pathways to address systemic exclusion in STEM.

Positioning Within Global Discourse

Barriers in Nyagatare mirror global gendered STEM exclusions while offering rural Sub-Saharan insights. Grounded in qualitative evidence and anchored in Critical Feminist, Social Cognitive, and Social Constructivist theories, this study advances a culturally embedded model for inclusive STEM reform. It enhances the academic relevance of GRSEM and positions Nyagatare as a reference in global discourse on gender equity and educational leadership.

Discussion

This study employed an explanatory sequential mixed-methods design to interrogate persistent gender disparities in STEM education across Nyagatare District, Rwanda. Guided by Critical Feminist Theory (hooks, 2000), Social Cognitive Theory (Bandura, 1997), and Social Constructivist Theory (Vygotsky, 1978), the findings affirm that gender inequalities are not biologically inherent but socially constructed, institutionally reproduced, and culturally normalised. Despite Rwanda's progressive education policies (MINEDUC, 2022), entrenched norms and structural biases continue to marginalise girls in STEM. The study, however, identifies disruptive potential in targeted, context-sensitive interventions.

Descriptive Norms and the Masculinisation of STEM

STEM remains largely masculinised, particularly in high-growth sectors like construction and engineering. Consistent with Ahmed's (2022) model of gendered curricular pipelines, the study reveals stark gendered clustering—boys dominate technical trades, while girls are tracked into caregiving and hospitality. These trajectories are institutionally reinforced, not merely reflective of choice, confirming global evidence on structural steering (Charles & Bradley, 2009).

Injunctive Norms and Regulated Aspirations

Qualitative findings show that **injunctive norms**—unspoken cultural expectations—discourage girls from pursuing STEM, citing fears of losing femininity or future marriageability. Bandura's (1997) concept of outcome expectancies explains this: the anticipation of negative social consequences deters ambition, even in capable learners. These subtle pressures normalise STEM disengagement and suppress autonomy.

Gendered Time Poverty

A unique insight from this research is the articulation of structural time poverty, whereby girls carry disproportionate domestic burdens, which reduces their academic focus. Echoing Martin (2017), the intersection of domestic labour and psychological discouragement impedes both opportunities and confidence—functioning as invisible but powerful exclusions in STEM education.

Stereotypes as Predictable and Addressable

Quantitative analysis revealed that male students were significantly more likely to endorse exclusionary STEM stereotypes. However, parental encouragement (Exp[B] = 0.668, $p = 0.004$) and exposure to inclusive role models showed strong negative associations with stereotype endorsement, consistent with Dasgupta & Stout (2014). Although career counselling's effect was marginal ($p = 0.09$), it showed promise when combined with psychosocial supports. These findings reinforce that stereotypes are socially learned—and can be unlearned through structured interventions.

Theoretical Synthesis and Validation of GRSEM

The Gender-Responsive STEM Equity Model (GRSEM) integrates and extends the study's guiding theories by mapping how Gender Biases and Stereotypes (GBS), School–Community Perceptions (SCP), and

Evidence-Based Interventions (EBI) shape Girls' STEM Participation (GWP). It positions individual belief systems, institutional practice, and cultural discourse as co-constructors of inequity. This multidimensional lens addresses intersectionality while offering scalable, policy-relevant interventions aligned with SDG 4 (Quality Education) and SDG 5 (Gender Equality).

Strategic Implications

Although the logistic regression model's Nagelkerke R^2 was moderate (0.132), key predictors—parental support and mentorship access—emerged as actionable levers. Interventions should include parent-focused education programmes, structured mentorship with female STEM professionals, and adoption of growth mindset pedagogy (Dweck, 2006) to build resilience and disrupt stereotype cycles.

Leadership and Policy Recommendations

Achieving gender equity in STEM requires visionary educational leadership. School leaders must foster inclusive pedagogies, dismantle implicit biases, and cultivate affirming learning environments. At the policy level, equity must be embedded through gender-sensitive curricula, teacher training, and data-driven monitoring systems. Furthermore, barriers such as structural time poverty necessitate innovative responses, including after-school programmes, flexible timetables, and community childcare initiatives.

From Framework to Ecosystem: The STEM Equity Ecosystem Model (SEEM)

To operationalise the Gender-Responsive STEM Equity Model (GRSEM), this study introduces the STEM Equity Ecosystem Model (SEEM) as depicted in Figure 4. SEEM represents a systemic reform strategy that connects school leadership, families, communities, and policymakers to promote sustainable, gender-inclusive change. It emphasises the visibility of female role models, collaborative governance, and the integration of context-sensitive interventions. By moving beyond fragmented efforts toward a coordinated ecosystem-wide approach, SEEM offers practical, scalable pathways for transforming STEM education in Sub-Saharan Africa and similar contexts.

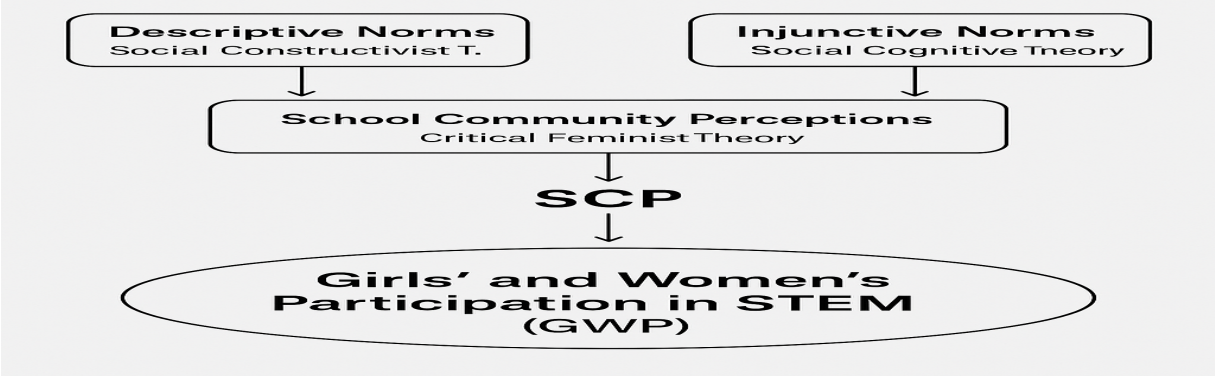

Figure 5: STEM Equity Ecosystem Model (SEEM) model

Integration of GRSEM and SEEM: Bridging Theory and Practice

This study integrates three interdependent pillars that collectively advance a transformative agenda for gender equity in STEM education. First, the Gender-Responsive STEM Equity Model (GRSEM), introduced in Section 1.4, offers a theory- and data-informed conceptual foundation. Second, the theoretical synthesis in Section 4.5 interweaves Critical Feminist, Social Cognitive, and Social Constructivist perspectives to

explain the mechanisms sustaining gendered exclusion. Third, the STEM Equity Ecosystem Model (SEEM), presented in Section 4.8, operationalises these insights into a strategic model for policy and leadership reform. Together, these elements constitute a coherent, context-sensitive, and globally translatable framework for gender-responsive educational leadership.

Study limitations and future directions

While this study offers rich, contextually embedded insights, its scope is limited to Nyagatare District. The cross-sectional design limits causal inference, and factors such as disability status and socioeconomic stratification were not thoroughly analysed. Future studies should adopt longitudinal, intersectional designs and test GRSEM and SEEM across broader regions to validate and adapt their applicability.

Conclusions

STEM gender disparities are not incidental; they are institutionally and socially reinforced through normative discourses, school tracking systems, and entrenched cultural expectations. Girls' autonomy is often curtailed by injunctive norms and social penalties, particularly in technical and science disciplines. Despite these structural obstacles, the study confirms that barriers are reversible. Evidence-based, gender-responsive interventions—rooted in family support, inclusive leadership, and culturally grounded mentoring—can shift the landscape of STEM participation in rural education settings.

The study offers two conceptual innovations: the Gender-Responsive STEM Equity Model (GRSEM) and the STEM Equity Ecosystem Model (SEEM). GRSEM presents a relational and systemic framework to understand the interplay between gendered beliefs, institutional practices, and community perceptions. SEEM operationalises this model into a practical framework for school and policy reform. This research enhances the field methodologically by demonstrating the power of mixed-methods research to surface nuanced social dynamics. It also contributes one of Rwanda's most comprehensive datasets on gender disparities in rural STEM education and equips leaders and policymakers with scalable models for inclusive educational leadership.

Gender equity in STEM requires multi-level action: policies must institutionalise gender-responsive pedagogy, integrate female role models, and adopt monitoring tools. Schools should establish Gender Equity Committees and mentorship networks, and address structural barriers. Communities must engage influencers to shift norms, while learners—especially girls—need early exposure to inclusive, inquiry-based STEM education to foster sustained participation.

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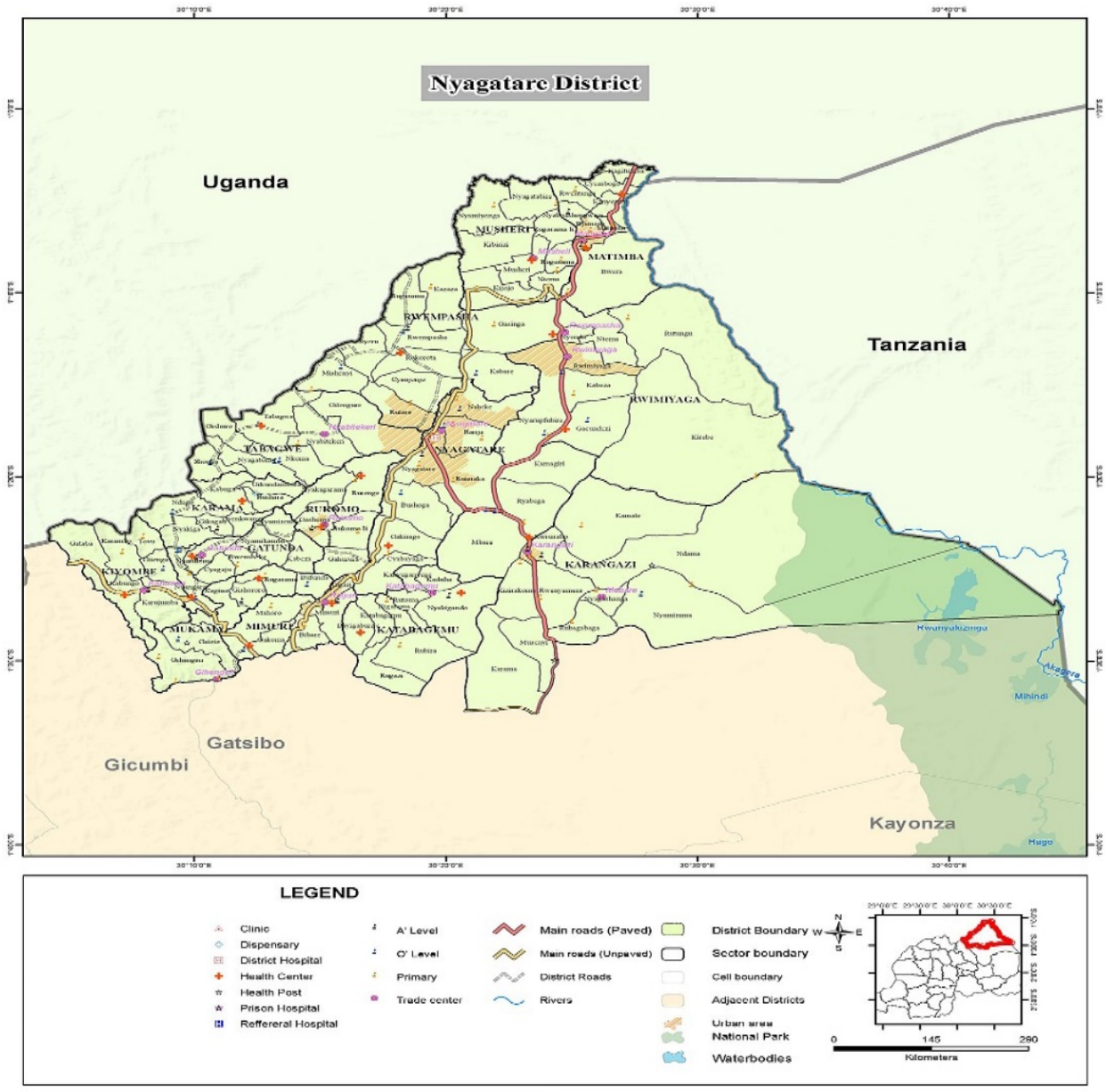
Appendix I: Map of Study Area



Source: (NISR, 2022)

Annex II: KII Interview Matrix Table

Code	Position / Role	Gender	Sector / Location	Date of Interview	Mode
KII-HT001	Headteacher – Secondary	Female	Kiyombe	10/4/2024	In-person
KII-HT003	Headteacher – Secondary	Male	Kiyombe	10/5/2024	In-person
KII-STU007	Student-Senior 6	Male	Mukama	11/3/2024	In-person
KII-STU010	Student – Senior 4	Female	Mukama	11/3/2024	In-person
KII-DEDU001	District Education Officer	Male	Nyagatare Town	12/18/2024	Phone
KII-SEI002	Sector Education Inspector	Male	Rwempasha	10/22/2024	In-person
KII-SECM2005	School Executive Committee Member	Male	Tabagwe	11/16/2024	Phone
KII-SEI006	Sector Education Inspector	Male	Katabagemu	10/28/2024	Phone

KIIs were conducted in all 14 sectors of Nyagatare District. Sectors not represented in this article include Karangazi*, Karama, Rwimiyaga, Matimba, Musheri, Rukomo, Gatunda, Mimuri. These are documented in the full PhD dissertation.*