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Early educational experiences and teacher gender bias in shaping female students' interest in Physics

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ABSTRACT

Gender disparities in physics persist globally, with female participation in STEM fields remaining disproportionately low in Ethiopia. Drawing on Situated Expectancy-Value Theory (SEVT) and Social Cognitive Theory (SCT) as interpretive frameworks, this study examined how early educational experiences, teacher influence, and gender bias shape female students' interest in physics in Kaffa Zone secondary schools in Southwest Ethiopia. A quantitative approach was employed to collect data from 352 female students using structured questionnaires. Exploratory factor analysis confirmed construct validity (KMO = 0.847), and reliability was excellent ($\alpha = 0.951$). Early educational experiences and exposure to female role models emerged as the strongest predictors of interest in physics. From a SEVT perspective, these findings suggest that formative experiences shape students' expectations for success and subjective task value, while from an SCT perspective, they highlight the importance of mastery experiences and vicarious learning in developing self-efficacy. Curriculum approaches and sociocultural influences also contributed significantly. Notably, teacher influence and gender bias were not significant predictors, suggesting evolving teacher attitudes in this context. This study underscores the critical importance of early exposure to science, visible female role models, and inclusive curricula in fostering girls' interest in physics.

KEYWORDS: Gender disparity; Physics education; Female role models; Early educational experiences; Teacher influence and gender bias; SEVT; SCT; STEM; Ethiopia

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1. Introduction

Gender inequality in science, technology, engineering, and mathematics (STEM) education remains a persistent global challenge despite considerable progress in expanding access to education. Women and girls continue to be underrepresented across STEM fields, often constituting a third or less of participants in education, employment, and innovation sectors (UNESCO, 2017, 2024). Recent data indicate that while women earn a larger share of bachelor's degrees overall, their representation in STEM fields remains notably lower (National Center for Education Statistics [NCES], 2023). This pattern is reflected globally, with similar disparities observed across Canada, the United Kingdom, Japan, and other nations (World Economic Forum [WEF], 2024). This disparity is not attributable to differences in ability; rather, it reflects systemic barriers, gender stereotypes, and unequal educational experiences that begin early in life and extend across academic and professional trajectories. Physics, in particular, consistently exhibits among the most pronounced gender disparities across scientific disciplines (Murphy & Whitelegg, 2006; UNESCO, 2017).

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Studies have indicated that gender disparities in STEM participation often emerge during secondary education and persist into higher education and professional careers (Wang & Degol, 2017). Multiple factors contribute to the lower participation of female students in physics. These include gender stereotypes, societal expectations, classroom experiences, and limited exposure to female role models (Dasgupta & Stout, 2014). Recent research has further highlighted that subtle gender dynamics in educational settings, such as differential task allocation in laboratory activities and comfort levels with hands-on equipment, can significantly influence female students' engagement with physics (Paul, 2026; Paul et al., 2025). In introductory physics laboratories, while overall participation rates may appear gender-neutral, significant differences emerge in task preferences: male students show greater preference and comfort with hands-on equipment handling, while female students gravitate toward analytical and documentation tasks (Paul, 2026). These patterns, combined with qualitative reports of exclusion from group discussions and reluctance to contribute in male-dominated groups (Paul et al., 2025), suggest that classroom micro-interactions play a significant role in shaping female students' engagement.

From a theoretical perspective, situated expectancy-value theory (SEVT) posits that students' academic choices are influenced by their expectations for success and the subjective value they attach to tasks, both of which are shaped by social contexts, cultural norms, and prior experiences (Eccles & Wigfield, 2002, 2020). Complementarily, social cognitive theory (SCT) emphasizes the role of self-efficacy—individuals' beliefs in their capabilities to perform specific tasks—which is developed through mastery experiences, vicarious learning, social persuasion, and emotional states (Bandura, 1986). Together, these theories provide a comprehensive framework for understanding how contextual factors shape students' academic interests and career aspirations.

The role of teacher influence in shaping these experiences is critical. Teacher influence encompasses not only instructional practices but also subtle ways teachers communicate expectations, provide feedback, and interact with students. Research suggests that teachers may unconsciously hold gender stereotypes regarding students' abilities in science and mathematics (Lavy & Sand, 2018). Such gender bias may appear in subtle classroom practices, including differences in questioning patterns, feedback, and the allocation of learning opportunities (Sadker et al., 2010). These biases can influence students' confidence, participation, and, ultimately, their interest in physics.

However, recent cross-national research reveals a troubling paradox: despite formal commitments to equality, many STEM teachers demonstrate limited awareness of how stereotypes, social expectations, and systemic inequalities affect girls' participation, instead attributing underrepresentation to personal choice or aptitude (Monteiro et al., 2025). This perception–practice gap underscores the need for deeper pedagogical transformation in science education.

Another important factor influencing female participation in STEM is the availability of role models. Exposure to successful female scientists can encourage girls to pursue science-related careers and challenge stereotypes about gender and scientific ability (Dasgupta & Stout, 2014). Recent research has refined our understanding of role model effectiveness: perceiving academic similarity to role models, particularly in terms of effort and abilities, positively predicts students' motivation to pursue STEM careers (Chen et al., 2026). Furthermore, interventions using video presentations of female role models have shown promise in increasing young women's expected sense of belonging in engineering contexts (Giese et al., 2025).

In Ethiopia, despite national policies aimed at promoting gender equality in education, female enrolment in university-level physics programmes remains disproportionately low (Egne, 2014; Semela, 2010). Cultural expectations, limited exposure to female role models, and teacher influence and gender bias that may not fully support female participation contribute to this imbalance. This study examines how early educational experiences, teacher influence, and gender bias shape female students' interest in physics in secondary schools in the Kaffa Zone of Southwest Ethiopia. Drawing on SEVT and SCT as interpretive frameworks, this study investigates the direct relationships between contextual factors and female students' engagement with physics.

1.1. Statement of the Problem

Despite global and national efforts to promote gender equality in education, female participation in physics and other STEM disciplines remains significantly lower than that of males. Research has shown that girls often demonstrate lower levels of interest and confidence in physics than boys, even when they have similar academic abilities (Wang & Degol, 2017). Recent studies have documented that while overall participation rates in physics laboratories may appear gender-neutral, significant disparities emerge in task preferences and comfort levels: male students tend to prefer and feel more comfortable with hands-on equipment handling and data collection, whereas female students more frequently prefer analytical and documentation tasks (Paul, 2026). Qualitative responses further reveal that some women experience exclusion from group discussions and reluctance to contribute ideas in male-dominated groups (Paul et al., 2025).

One explanation for these disparities is that students' interest in science subjects is shaped by a combination of educational experiences, social influences, and classroom practices. Early exposure to science learning activities can significantly influence students' motivation to pursue science-related fields (Hazari et al., 2010). Recent intervention research demonstrates that early STEM exposure through hands-on activities can significantly enhance girls' self-efficacy, interest, and career aspirations, while fostering a sense of belonging and willingness to challenge gender-based stereotypes (Miranda, 2025). Similarly, experimental studies with young children have shown that role-playing as scientists boosts girls' persistence in science activities (Huang et al., 2026).

Teachers also play a critical role in shaping students' learning experiences through their influence and potential gender bias (Lavy & Sand, 2018; Sadker et al., 2010). However, recent cross-national research reveals a troubling paradox: despite formal commitments to equality, many STEM teachers demonstrate limited awareness of how stereotypes, social expectations, and systemic inequalities affect girls' participation (Monteiro et al., 2025). In Ethiopia, although girls' participation in education has improved, female representation in STEM fields remains limited (Egne, 2014). Therefore, this study aims to investigate the role of early educational experiences, teacher influence, and gender bias in shaping female students' interest in physics in secondary schools in the Kaffa Zone, Southwest Ethiopia.

1.2. Research Questions

The study is guided by the following research questions:

1. How do early educational experiences influence female students' interest in physics?
2. To what extent do teachers influence, and gender bias (e.g., instructional methods, feedback, encouragement, and equitable treatment) affect female students' interest in physics?
3. How inclusive is the physics curriculum and teaching methods in addressing the needs of female students in Kaffa Zone secondary schools?
4. What impact do female role models in science have on shaping female students' interest in physics?

5. How do societal expectations and cultural norms influence female students' perceptions of physics and their engagement with the subject?
6. To what extent do early educational experiences, teacher influence, gender bias, curriculum approaches, role models, and sociocultural factors jointly predict female students' interest in physics?

1.3. Objectives of the Study

The general objective of this study was to investigate the role of early educational experiences, teacher influence, and gender bias in shaping female students' interest in physics in Kaffa Zone secondary schools in Southwest Ethiopia.

Specific objectives:

1. Examine the influence of early educational experiences on female students' interest in physics.
2. Analyze the impact of teacher influence and gender bias (including encouragement, feedback, equitable treatment, and classroom interactions) on female students' interest in physics.
3. Assess the inclusiveness of the physics curriculum and teaching methods regarding female students.
4. Influence of female role models in science on female students' interest in physics.
5. Analyze the impact of societal expectations and cultural norms on female students' interest and participation in physics.
6. Determine the combined effect of early educational experiences, teacher influence and gender bias, curriculum approaches, role models, and sociocultural factors on female students' interest in physics.

2. Literature Review

2.1. Theoretical Foundations: SEVT and SCT

Understanding female students' participation in physics requires a strong theoretical grounding in motivation and learning. This study draws on two complementary theoretical frameworks—Situated Expectancy-Value Theory (SEVT) and Social Cognitive Theory (SCT)—to interpret the relationships between contextual factors and female students' interest in physics.

Situated Expectancy-Value Theory (SEVT), as developed by Eccles and colleagues, posits that students' achievement-related choices are primarily determined by two key factors: their expectations for success and the subjective task value they attach to a domain (Eccles & Wigfield, 2002, 2020). Expectations for success refer to students' beliefs about their ability to succeed in a given task, while subjective task value comprises multiple components: intrinsic value (enjoyment of the task), utility value (perceived usefulness for future goals), attainment value (importance of doing well for one's identity), and cost (perceived barriers). Importantly, these motivational beliefs are not formed in isolation but are shaped by social contexts, cultural norms, and prior experiences (Eccles & Wigfield, 2020).

Social Cognitive Theory (SCT), proposed by Bandura (1986), emphasizes the role of self-efficacy—individuals' beliefs in their capabilities to successfully perform specific tasks—as a central mechanism in motivation and behavior. According to SCT, self-efficacy is developed through four primary sources: mastery experiences (past successes), vicarious learning (observing similar others succeed), social persuasion (encouragement from others), and emotional and physiological states. In educational contexts, SCT highlights the importance of teacher influence as a source of social persuasion and modeling, and role models as sources of vicarious learning (Bandura, 1986).

Together, SEVT and SCT provide a comprehensive framework for understanding how contextual factors influence female students' interest in physics. This study uses these theories as interpretive frameworks to understand the direct relationships observed among early educational experiences, teacher influence, gender bias, role models, sociocultural influences, and female students' interest in physics.

2.2. Gender Disparities in STEM Education

The underrepresentation of women in STEM fields is a well-documented global phenomenon. Physics, in particular, exhibits one of the most pronounced gender gaps among scientific disciplines (Murphy & Whitelegg, 2006; UNESCO, 2017). Although women constitute a large proportion of students in general education, their representation declines significantly in advanced science fields, a phenomenon commonly described as the "leaky pipeline" (Blickenstaff, 2005). Recent data confirm that this pattern persists globally, with women earning only 38% of STEM bachelor's degrees despite constituting 58% of all degree recipients (NCES, 2023; WEF, 2024).

This pattern often begins during the early stages of schooling, where social stereotypes, cultural expectations, and unequal educational experiences influence students' perceptions of science (Hazari et al., 2010). By age six, children already associate science with men and are more likely to draw men than women when asked to draw a scientist (Miller et al., 2018). Around the same age, girls become less likely than boys to express interest in activities described as being for "really, really smart" children (Bian et al., 2017). Recent laboratory-based research has uncovered subtle gender dynamics that may contribute to these disparities (Paul, 2026; Paul et al., 2025).

2.3. Influence of Early Educational Experiences

Early educational experiences play a critical role in shaping students' attitudes toward science and their future academic choices. Research has shown that early exposure to science through hands-on activities, teacher encouragement, and participation in science-related activities significantly increases students' likelihood of pursuing STEM fields (Tenenbaum & Leaper, 2003). Recent intervention studies have provided compelling evidence for the effectiveness of early STEM exposure. Miranda (2025) examined the impact of a hands-on STEM program for fifth-grade girls and found significant enhancements in participants' interest, self-efficacy, and career aspirations, as well as an increased sense of belonging and willingness to challenge gender-based stereotypes. Experimental research with young children has demonstrated that even brief interventions, such as pretending to be a scientist during a science activity, can boost girls' persistence in science tasks (Huang et al., 2026).

From an SEVT perspective, early educational experiences contribute to the development of both expectancy beliefs and task value. When female students have positive experiences with science in primary school, they are more likely to develop higher expectations for success and greater intrinsic and utility value for physics (Eccles & Wigfield, 2020). From an SCT perspective, early experiences serve as critical sources of mastery experiences. Successful completion of science tasks builds self-efficacy, which in turn influences future engagement and persistence (Bandura, 1986).

2.4. Teacher Influence and Gender Bias in Science Classrooms

Teacher influence encompasses various ways teachers shape students' engagement with academic subjects through their instructional approaches, expectations, encouragement, and classroom interactions. Research suggests that teachers may sometimes hold unconscious gender stereotypes regarding students' abilities in science and mathematics (Lavy & Sand, 2018). Such gender bias may appear in subtle classroom practices, including differences in questioning patterns, feedback, and the allocation of learning opportunities (Sadker et al., 2010). When teachers provide more attention, encouragement, or challenging tasks to male students, they may inadvertently communicate that physics is more appropriate or attainable for boys than for girls.

Recent research has complicated our understanding of teacher influence and gender bias by revealing a significant perception–practice gap. Monteiro et al. (2025) conducted a cross-national study of STEM teachers and found that, while most teachers formally affirm gender equality in principle, they show limited awareness of the structural and cultural barriers girls face in STEM. These findings are particularly relevant to physics education, where subtle gender dynamics can significantly affect student engagement (Paul, 2026; Paul et al., 2025).

From an SEVT perspective, teacher influence shapes students' expectations and task values by structuring learning activities, providing feedback, and framing the relevance of subject content. From an SCT perspective, teachers serve as key agents of social persuasion and modeling. Interventions that provide positive feedback on ability have been shown to increase women's self-efficacy and interest in engineering domains (Giese et al., 2025).

2.5. Curriculum and Instructional Approaches in Physics Education

The structure and delivery of physics curricula can influence students' engagement with the subject. Traditional physics instruction often emphasizes abstract concepts and mathematical problem-solving, which may not always connect with students' everyday experiences (Murphy & Whitelegg, 2006). Studies suggest that contextualized teaching approaches that relate physics concepts to real-world situations can improve students' motivation and understanding (Haussler & Hoffmann, 2002). Instructional strategies, such as collaborative learning, inquiry-based activities, and practical experiments, can make physics learning more accessible and engaging for students. Recent research on active learning demonstrates that student-centred approaches significantly enhance performance and engagement across STEM disciplines (Freeman et al., 2014).

The design of laboratory experiences warrants particular attention, given recent findings on gender dynamics in these settings. Paul et al. (2025) found that qualitative feedback from female students often highlights challenges related to gender dynamics, including perceived assumptions about competence, being overlooked during discussions, and hesitation to voice opinions in male-dominated groups. These findings underscore the need for instructional strategies that actively promote equitable participation in laboratory settings.

2.6. Role Models and Mentorship in STEM

The presence of female role models in STEM fields plays an important role in motivating female students to pursue science-related careers. Role models challenge stereotypes and provide visible examples of success in scientific fields (Dasgupta & Stout, 2014). The stereotype inoculation model (Dasgupta, 2011) posits that exposure to ingroup members in stereotyped domains functions as a "social vaccine," increasing belongingness and protecting against stereotype threat.

Recent research has significantly advanced our understanding of the factors that make role models effective. Chen et al. (2026) found that perceiving academic similarity—in terms of abilities, interests, or efforts—positively and robustly predicted students' STEM career motivation, whereas demographic similarity played a more limited role. Experimental studies have also demonstrated the effectiveness of role model interventions. Bleiberg et al. (2025) conducted a randomized controlled trial and found that girls assigned to female mathematics tutors showed significantly higher STEM interest (0.73 standard deviations) and were 3.9% more likely to earn at least a C- in Algebra I than girls assigned to male tutors.

In Ethiopia, as in many educational contexts, the number of female physics teachers and professionals remains limited. This lack of representation may restrict female students' opportunities to identify with same-gender role models in science. Mentorship programs connecting female students with women working in STEM fields have been shown to improve students' motivation, academic confidence, and career aspirations internationally (Packard, 2016).

2.7. Societal and Cultural Influences

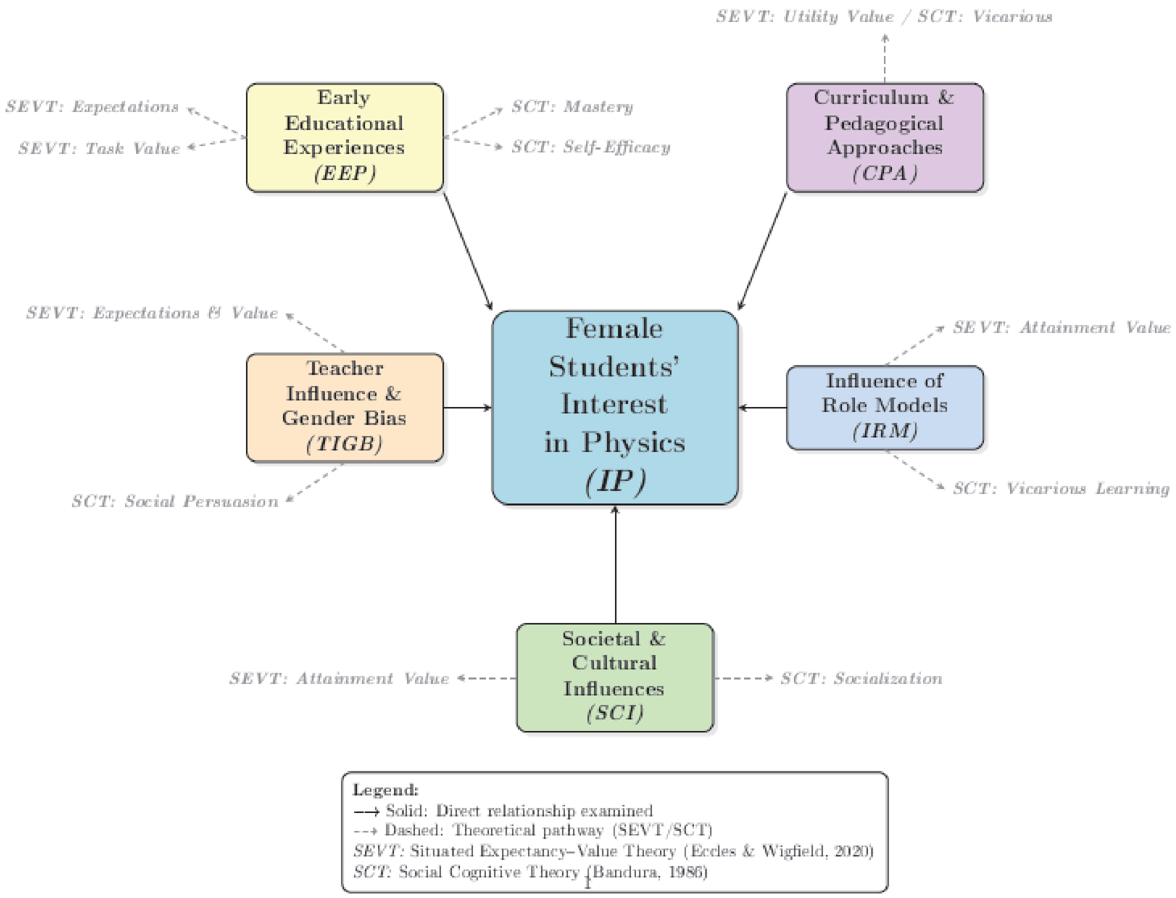
Students' academic choices are also shaped by broader societal and cultural influences. In many societies, traditional gender roles may discourage girls from pursuing careers in science and technology (Colclough et al., 2000). Family expectations, community attitudes, and media representations can influence students' perceptions of which subjects are appropriate for males or females. Recent research has highlighted the importance of social networks and peer relationships in shaping girls' STEM trajectories. Chen et al. (2026) found that objective social inclusion, particularly by male peers, was associated with stronger STEM intentions for girls, mediated by subjective belonging.

In Ethiopia, cultural norms and limited awareness of STEM career opportunities may influence female students' participation in science education (Egne, 2014). These influences may interact with classroom experiences, affecting students' interest and confidence in subjects such as physics.

2.8. Conceptual Framework

Based on the reviewed literature, this study proposes a conceptual framework (Figure 1) in which female students' interest in physics is influenced by multiple interconnected factors: early educational experiences, teacher influence and gender bias, curriculum and instructional approaches, exposure to female role models, and societal and cultural influences. Drawing on SEVT (Eccles & Wigfield, 2020), early educational experiences shape students' expectations for success and subjective task value in physics. From the perspective of SCT (Bandura, 1986), teacher influence and exposure to role models serve as sources of social persuasion and vicarious learning, contributing to the development of self-efficacy beliefs.

Figure 1 ***Conceptual Framework Illustrating Factors Influencing Female Students' Interest in Physics.***



3. Method

3.1. Research Design and Approach

This study employed a quantitative research design using a descriptive survey approach to examine the factors influencing female students' interest in physics. Descriptive survey designs are appropriate for investigating existing conditions, perceptions, and relationships among variables within a specific population (Creswell & Creswell, 2018). A quantitative research approach was adopted to examine the relationships between the independent variables (early educational experiences, teacher influence and gender bias, curriculum and instructional approaches, exposure to female role models, and societal and cultural influences) and the dependent variable (female students' interest in physics).

3.2. Study Area and Population

The study was conducted in the Kaffa Zone, Southwest Ethiopia, which is approximately 460 km from Addis Ababa. The area comprises both urban and rural settings, with several government secondary schools representing diverse socio-cultural contexts. The region was selected because of its limited female representation in science fields, particularly in physics (Egne, 2014; Semela, 2010). The target population comprised female students enrolled in Grades 9, 10, 11, and 12 who were studying physics during the 2024/2025 academic year. According to records from the Kaffa Zone Education Office, the total number of female students enrolled in physics across the four selected schools was approximately 1,200.

3.3. Sampling Technique and Sample Size

A multistage sampling technique was employed. First, four secondary schools (Gimbo Secondary School, Bishaw W/Yohannis Secondary School, Shishonde Secondary School, and Awrada Secondary School) were selected using purposive sampling based on: (a) accessibility, (b) presence of Grades 9–12, and (c) inclusion of both urban and rural schools. Second, the female student population within each school was stratified by grade level. Finally, participants were selected using simple random sampling within each stratum using the lottery method.

The sample size was determined using a single-population proportion formula with a 95% confidence interval:

$$n = Z^2 p(1-p) / e^2 = (1.96)^2 \times 0.5(1-0.5) / (0.05)^2 = 384$$

where n is the minimum sample size, p = 50%, e is the margin of error (5%), and Z is the Z-score (1.96 for a 95% confidence level). Of the 384 distributed questionnaires, 352 were completed and returned, yielding a response rate of 91.7%.

3.4. Data Collection Instruments

Structured questionnaires were administered to female students currently enrolled in physics subjects. The questionnaire was developed by the researcher based on established instruments in STEM education research (Hazari et al., 2010; Lavy & Sand, 2018; Tenenbaum & Leaper, 2003) and adapted to the Ethiopian secondary school context. All items were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Table 1 presents a summary of the questionnaire structure.

Table 1 ***Summary of Questionnaire Structure***

Sub-Dimension	Items	Scale Type	Sample Item
Independent Variables			
Early Educational Experiences	6	5-point Likert	"My teachers in primary school encouraged me to explore science subjects."
Teacher Influence and Gender Bias	6	5-point Likert	"My physics teacher encourages me to pursue a career in physics."
Curriculum and Pedagogical Approaches	4	5-point Likert	"The teaching methods used in my physics class are engaging and help me understand the material."
Influence of Role Models	4	5-point Likert	"Seeing female scientists in textbooks, media, or in person encourages me to pursue physics."
Societal and Cultural Influences	4	5-point Likert	"Cultural expectations sometimes discourage girls from pursuing subjects like physics."
Dependent Variable			
Interest in Physics	5	5-point Likert	"I find physics interesting and engaging."
Total	**29**		

Note. Response items were measured using a 5-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.

3.5. Operationalization and Measurement of Variables

Dependent variable: Interest in Physics (IP) — self-reported interest, engagement, and motivation in physics studies and careers among female students.

Independent variables: Early Educational Experiences (EEP) — students' perceptions of their early exposure to science education, encouragement from primary school teachers, family support, and participation in science-related activities; Teacher Influence and Gender Bias (TIGB) — students' perceptions of their physics teachers' encouragement, equitable treatment, and classroom practices; Curriculum and Pedagogical Approaches (CPA) — students' perceptions of the relevance and inclusiveness of physics curriculum content and teaching methods; Influence of Role Models (IRM) — students' exposure to and perceptions of female role models in physics and STEM fields; Societal and Cultural Influences (SCI) — students' perceptions of community attitudes, cultural expectations, and family support regarding female participation in physics.

3.6. Validity and Reliability

To ensure content validity, the instruments were reviewed by a panel of three experts in science education and gender studies. A pilot study was conducted with 26 students from a neighboring school not included in the final sample. Construct validity was assessed using principal component analysis (PCA) with Varimax rotation. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.847, exceeding the recommended threshold of 0.60 (Kaiser, 1974). Bartlett's test of sphericity was significant ($\chi^2 = 2640.313$, df = 406, $p < .001$), confirming suitability for factor analysis (Tabachnick & Fidell, 2019). The factor analysis extracted nine components with eigenvalues greater than 1.0, accounting for 59.65% of the total variance.

The reliability of the questionnaire was evaluated using Cronbach's alpha coefficient. The overall instrument demonstrated excellent internal consistency, with a Cronbach's alpha of 0.951 (Cronbach, 1951). Reliability coefficients for individual constructs ranged from 0.701 to 0.924. Table 2 presents the reliability statistics.

Table 2 ***Reliability Statistics for Study Constructs***

Construct	Cronbach's Alpha	Number of Items
Early Educational Experiences (EEP)	0.854	6
Teacher Influence and Gender Bias (TIGB)	0.897	6
Curriculum and Pedagogical Approaches (CPA)	0.701	4
Influence of Role Models (IRM)	0.924	4
Societal and Cultural Influences (SCI)	0.900	4
Interest in Physics (IP)	0.874	5
Overall Instrument	0.951	29

Note. All reliability coefficients exceeded the recommended threshold of 0.70 (Numally & Bernstein, 1994).

3.7. Data Analysis

After data collection, the completed questionnaires were edited for completeness, coded, and entered into SPSS version 23. The data were analyzed using both descriptive and inferential statistics.

Descriptive statistics (frequencies, percentages, means, and standard deviations) were used to summarize demographic characteristics and study variables. Inferential statistics, including Pearson's correlation analysis and multiple regression analysis, were used to examine relationships and identify significant predictors of interest in physics.

3.8. Model Specification

Linear regression analysis was conducted to model the relationship between the dependent and independent variables:

$$IP = f(EEP, TIGB, CPA, IRM, SCI)$$

Transforming into a multiple regression model:

$$IP = \beta_0 + (\beta_1 \times EEP) + (\beta_2 \times TIGB) + (\beta_3 \times CPA) + (\beta_4 \times IRM) + (\beta_5 \times SCI)$$

where β_0 = constant; β_1, β_2, β_3, β_4, and β_5 = regression coefficients.

3.9. Ethical Considerations

The study adhered to ethical standards in research and ensured informed consent from all participants. Confidentiality was maintained, and participants were assured that their responses would be used solely for research purposes. Permission was obtained from the relevant educational authorities and school administrations before data collection.

4. Findings

4.1. Response Rate and Demographic Characteristics

Of the 384 questionnaires distributed, 352 were completed and returned, representing a response rate of 91.7%, which is more than sufficient for generalization (Ary et al., 2014). The demographic characteristics are summarized in Table 3. The largest age group was 15–17 years (48.3%), followed by those under 15 years (32.7%). Most respondents were in the 10th grade (53.4%), followed by the 9th grade (32.4%). The majority of students (73.6%) were taught by male physics teachers, highlighting a gender imbalance in STEM education. More than half of the respondents' parents (54.5%) had only primary education.

Table 3 ***Demographic Characteristics of Participating Students***

Variable	Category	%
Age	Under 15	32.7
	15–17	48.3
	18–20	12.5
	Above 20	6.5
Grade level	9th	32.4
	10th	53.4
	11th	4.3
	12th	9.9

Variable	Category	%
Teacher Gender	Students taught by female physics teachers	26.4
	Students taught by male physics teachers	73.6
Parents' Educational Background	Uneducated	11.6
	Primary	54.5
	Secondary	16.5
	Graduate or post-graduate	17.3

4.2. Descriptive Statistics of Study Variables

Table 4 presents the descriptive statistics for the key study variables. The mean interest in physics was 3.49 (SD = 0.89), indicating a moderate level of engagement among female students. Early educational experiences had a mean of 3.39 (SD = 0.81), while teacher influence and gender bias scored 3.58 (SD = 0.67). Curriculum and pedagogical approaches received the highest mean score (3.78, SD = 0.68), and societal and cultural influences received the lowest (2.99, SD = 0.83).

Table 4 ***Descriptive Statistics of Key Study Variables***

Variable	Mean	Standard Deviation
Early Educational Experiences (EEP)	3.39	0.81
Teacher Influence and Gender Bias (TIGB)	3.58	0.67
Curriculum and Pedagogical Approaches (CPA)	3.78	0.68
Influence of Role Models (IRM)	3.46	0.88
Societal and Cultural Influences (SCI)	2.99	0.83
Interest in Physics (IP)	3.49	0.89

Note. N = 352. All variables were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

4.3. Correlation Analysis

Pearson's correlation analysis was conducted to assess the relationships between the independent variables and students' interest in physics. Table 5 presents the correlation coefficients. Early educational experiences were strongly correlated with interest in physics ($r = 0.591$, $p < .001$), followed by the influence of role models ($r = 0.526$, $p < .001$). Teacher influence and gender bias ($r = 0.459$, $p < .001$), societal and cultural influences ($r = 0.386$, $p < .001$), and curriculum and pedagogical approaches ($r = 0.365$, $p < .001$) also showed significant but weaker correlations.

Table 5 ***Pearson Correlation Coefficients Between Study Variables***

	IP	EEP	TIGB	CPA	IRM
IP	1.000				

	IP	EEP	TIGB	CPA	IRM
EEP	0.591**	1.000			
TIGB	0.459**	0.581**	1.000		
CPA	0.365**	0.346**	0.434**	1.000	
IRM	0.526**	0.455**	0.461**	0.284*	1.000
SCI	0.386**	0.367**	0.330**	0.225**	0.397**

*Note. N = 352. IP = Interest in Physics; EEP = Early Educational Experiences; TIGB = Teacher Influence and Gender Bias; CPA = Curriculum and Pedagogical Approaches; IRM = Influence of Role Models; SCI = Societal and Cultural Influences. ** p < .001; * p < .05.*

4.4. Regression Analysis

4.4.1. Assumption Testing

Before conducting the multiple regression analysis, the assumptions of normality, linearity, homoscedasticity, and absence of multicollinearity were tested. The normal probability plot (P-P plot) confirmed that the residuals were normally distributed. Scatterplots confirmed linearity and homoscedasticity. Multicollinearity was assessed using the variance inflation factor (VIF) and tolerance statistics. All VIF values were below 2 (ranging from 1.263 to 1.772), and tolerance values were above 0.1 (ranging from 0.564 to 0.792) (Table 6), indicating no multicollinearity issues (Field, 2018). The Durbin-Watson statistic was 1.629 (Table 7), suggesting no significant autocorrelation in the residuals.

Table 6 ***Collinearity Statistics***

Collinearity Statistics		
	Tolerance	**VIF**
EEP	0.596	1.678
TIGB	0.564	1.772
CPA	0.792	1.263
IRM	0.687	1.456
SCI	0.791	1.265

4.4.2. Model Summary

The regression model explained 46.0% of the variance in female students' interest in physics (R^2 = 0.460, Adjusted R^2 = 0.452, F(5, 346) = 58.864, p < .001). This indicates that the independent variables collectively accounted for nearly half of the variation in students' interest in physics.

Table 7 ***Model Summary***

Model	R	R^2	Adj. R^2	Std. Error	Durbin-Watson
1	0.678	0.460	0.452	0.66028	1.629

4.4.3. Regression Coefficients

Table 8 presents the regression coefficients. Early educational experiences (β = 0.405, p < .001) and the influence of role models (β = 0.270, p < .001) were the strongest predictors of interest in physics. Curriculum and pedagogical approaches (β = 0.161, p = .006) and societal and cultural influences (β = 0.114, p = .018) also significantly contributed to the model. Teacher influence and gender bias were not significant predictors (β = 0.045, p = .524).

Table 8 ***Multiple Regression Coefficients for Predictors of Physics Interest***

Predictor	Unstd. β	Std. Error	Std. β	t	p-value
(Constant)	0.072	0.239		0.299	0.765
EEP	0.405	0.056	0.369	7.215	0.000
TIGB	0.045	0.070	0.034	0.637	0.524
CPA	0.161	0.058	0.123	2.777	0.006
IRM	0.270	0.048	0.266	5.575	0.000
SCI	0.114	0.048	0.106	2.383	0.018

The resulting regression equation is:

$$IP = 0.072 + (0.405 \times EEP) + (0.161 \times CPA) + (0.270 \times IRM) + (0.114 \times SCI)$$

4.5. Summary of Results

The key findings from the statistical analysis are:

- Early educational experiences had the strongest positive relationship with physics interest (r = 0.591, β = 0.405, p < .001), indicating that students with more positive early science experiences reported higher interest in physics.
- The influence of role models was strongly positively related to physics interest (r = 0.526, β = 0.270, p < .001), suggesting that exposure to female role models significantly enhances interest.
- Curriculum and pedagogical approaches had a moderate positive relationship with physics interest (r = 0.365, β = 0.161, p = .006), indicating that inclusive and engaging teaching methods contribute to interest.
- Societal and cultural influences had a modest positive relationship with physics interest (r = 0.386, β = 0.114, p = .018), suggesting that supportive community attitudes enhance interest.
- Teacher influence and gender bias were not significant predictors (β = 0.045, p = .524), contrary to expectations based on previous research.

5. Discussion

The findings of this study provide important insights into the factors influencing female students' interest in physics in Ethiopian secondary schools, interpreted through the complementary lenses of SEVT and SCT. The regression model explained 46.0% of the variance in physics interest, with early educational experiences and exposure to female role models emerging as the strongest predictors.

5.1. The Strong Influence of Early Educational Experiences

The findings revealed that early educational experiences were the strongest predictors of female students' interest in physics. Students who reported positive early exposure to science learning activities were more likely to demonstrate interest in physics. This finding is consistent with a substantial body of research showing that early engagement with science significantly influences students' attitudes toward STEM subjects (Hazari et al., 2010). These results align with recent intervention studies: Miranda (2025) found that hands-on STEM programs for elementary-aged girls significantly enhanced participants' interest, self-efficacy, and career aspirations. Similarly, experimental research by Huang et al. (2026) showed that even brief interventions, such as pretending to be a scientist, can boost girls' persistence in science activities.

According to SEVT (Eccles & Wigfield, 2020), positive early science learning experiences can increase students' confidence and the perceived value of science education, thereby increasing their likelihood of pursuing physics at higher levels of study. The strong predictive power of early experiences in this study suggests that interventions targeting elementary science education may be particularly effective in promoting gender equity in physics.

5.2. The Role of Female Role Models

The results also indicated that exposure to female role models significantly influenced female students' interest in physics. Students who were aware of successful women in science fields showed greater motivation to pursue physics. This finding supports previous research indicating that female role models can help challenge stereotypes about gender and scientific ability (Dasgupta & Stout, 2014). Recent research by Chen et al. (2026) found that perceiving academic similarity—particularly in terms of effort—to role models positively predicts STEM career motivation, especially for students from marginalized groups. Bleiberg et al. (2025) demonstrated that girls assigned to female mathematics tutors showed significantly higher STEM interest and improved course performance. These findings have important implications for the Ethiopian context, where increasing the visibility of female scientists and physics teachers could significantly enhance girls' motivation.

5.3. The Impact of Curriculum and Teaching Methods

The findings also revealed that curriculum and instructional approaches significantly influenced female students' interest in physics. Student-centered teaching approaches allow learners to actively participate in the learning process, thereby enhancing motivation and interest. Hands-on learning experiences are particularly important in physics education because they allow students to connect abstract concepts with real-world applications (Haussler & Hoffmann, 2002). The design of laboratory experiences deserves particular attention in light of recent research on gender dynamics: Paul (2026) found significant differences in task preferences and comfort levels, while Paul et al. (2025) documented qualitative reports from female students describing exclusion from group discussions. These findings suggest that educators must be intentional about promoting equitable participation.

5.4. The Moderate Effect of Societal and Cultural Influences

Sociocultural factors also influenced female students' interest in physics. Family encouragement and positive societal attitudes toward science careers contributed to higher levels of student motivation. Recent research by Chen et al. (2026) found that objective social inclusion, particularly by male peers, was associated with stronger STEM intentions for girls. In Ethiopia, where traditional gender roles may influence educational choices, community awareness programs and family engagement initiatives could play an important role in supporting girls' science education.

5.5. Teacher Influence and Gender Bias

Contrary to expectations based on previous research (Lavy & Sand, 2018; Sadker et al., 2010), teacher influence and gender bias did not emerge as significant predictors of female students' interest in physics. This finding suggests that students in the sampled schools may not perceive discriminatory treatment from teachers as strongly. The mean score for teacher influence and gender bias (M = 3.58, SD = 0.67) suggests that students generally perceive teachers as relatively supportive. This may indicate that teacher attitudes toward gender equity in science education are evolving positively in this context. Additionally, students may not interpret teacher behaviors as gender-biased, even if subtle differences exist, consistent with the perception–practice gap documented by Monteiro et al. (2025). Other factors, such as early experiences and role models, may have stronger influences that overshadow the effects of teacher bias.

5.6. Theoretical Implications

The findings support the use of SEVT and SCT as interpretive frameworks for understanding the direct relationships between contextual factors and female students' interest in physics. The strong effects of early educational experiences (interpreted through SEVT as shaping expectations and task value, and through SCT as providing mastery experiences) and role models (interpreted through SCT as vicarious learning) highlight how both motivational beliefs and social-cognitive processes operate simultaneously to shape engagement. The non-significant finding for teacher gender bias raises important questions about the mechanisms through which teachers influence female students' motivation, consistent with SCT's emphasis on social persuasion as a key source of self-efficacy (Bandura, 1986).

6. Conclusion and Recommendations

6.1. Conclusions

This study examined the roles of early educational experiences, teacher influence and gender bias, curriculum and instructional approaches, female role models, and sociocultural influences in shaping female students' interest in physics in secondary schools in the Kaffa Zone, Southwest Ethiopia. The results indicate that early educational experiences play a critical role in shaping female students' interest in physics, consistent with recent intervention research (Miranda, 2025; Huang et al., 2026). Female role models significantly influence students' motivation, with recent research emphasizing the importance of perceived academic similarity (Chen et al., 2026). Curriculum and instructional approaches, as well as sociocultural influences, also had significant effects. However, teacher influence and gender bias did not show statistically significant effects, which may reflect the complexity of measuring perceived bias or indicate positive changes in teachers' attitudes.

6.2. Recommendations

6.2.1. Strengthening Early Science Education

Educational policymakers and curriculum developers should strengthen science education at the primary and lower secondary levels. Schools should encourage practical science activities, inquiry-based learning, and hands-on experiments to stimulate students' curiosity. Evidence from intervention studies (Miranda, 2025; Huang et al., 2026) suggests that even brief, well-designed early interventions can have lasting impacts on girls' engagement in science.

6.2.2. Promoting Equitable Teacher Influence and Addressing Gender Bias

Teachers should adopt inclusive and equitable practices. Given recent findings on subtle gender dynamics in laboratory settings (Paul, 2026; Paul et al., 2025), teachers should be particularly attentive to ensuring equitable task allocation. Professional development programs should address the perception–practice gap identified by Monteiro et al. (2025), emphasizing the importance of providing equal encouragement, feedback, and opportunities to all students, regardless of gender.

6.2.3. Increasing Visibility of Female Role Models in STEM

Educational institutions should promote the visibility of female scientists through mentorship programs, guest lectures, and career guidance activities. Research suggests that emphasizing academic similarity—particularly shared efforts and challenges—may enhance role model effectiveness (Chen et al., 2026). Evidence from randomized controlled trials demonstrates that gender-matched tutoring can significantly improve girls' STEM outcomes (Bleiberg et al., 2025).

6.2.4. Improving Curriculum and Instructional Approaches

Curriculum developers and educators should design instructional materials that connect physics concepts with real-life applications. Given documented gender differences in task preferences within laboratory settings, instructors should structure activities to ensure that all students gain experience with both hands-on equipment and analytical tasks (Paul, 2026).

6.2.5. Addressing Sociocultural Barriers

Awareness programs should be organized to challenge gender stereotypes and promote positive attitudes toward girls' participation in science. Schools, families, and communities should work together to encourage female students to pursue science education and careers in STEM fields. Recent research highlighting the importance of peer networks (Chen et al., 2026) suggests that fostering inclusive friendship groups within STEM contexts may be a valuable strategy.

6.2.6. Recommendations for Future Research

Future studies may explore additional factors influencing female students' participation in physics, including peer networks, students' self-efficacy beliefs, and school resources. Qualitative research approaches, including classroom observations and in-depth interviews, could provide deeper insights into subtle gender dynamics (Paul et al., 2025). Comparative studies across different regions of Ethiopia would help determine whether the findings can be generalized. Future research should also include explicit measures of teacher influence and gender bias using multiple methods, including classroom observations.

6.3. Limitations of the Study

This study has several limitations. First, the use of self-report questionnaire data may not fully capture the complexity of students' experiences, particularly subtle gender dynamics documented through qualitative methods (Paul et al., 2025). Second, the study was conducted only in selected secondary schools in the Kaffa Zone, which limited its generalizability. Third, other important variables, such as peer networks (Chen et al., 2026), students' self-efficacy beliefs, parental support, and specific school resources, were not included. Fourth, the cross-sectional design limits the ability to establish causal relationships. Finally, incorporating qualitative methods could provide deeper insights into students' experiences.

7. Declarations

7.1. Author Contributions (CRediT)

Tewodros Adaro Gatissa: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review and Editing, Visualization, Project Administration. The author has read and approved the final version of the manuscript and takes full responsibility for all aspects of the work.

7.2. Conflict of Interest

The author declares no financial, commercial, institutional, or personal relationships that could have appeared to influence the work reported in this paper. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

7.3. Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to ethical considerations and the need to protect participant confidentiality, the data are not publicly accessible. However, they may be shared with qualified researchers who provide evidence of appropriate institutional ethical approval and agree to comply with relevant data protection regulations.

7.4. Funding Statement

This research received no specific grant from any public, commercial, or not-for-profit funding agency. The study was conducted independently, without external financial support.

7.5. Ethics Approval

Prior to data collection, permission was obtained from the relevant educational authorities and school administrations in accordance with standard research ethics procedures. All participants were fully informed about the purpose, scope, and voluntary nature of the study before providing their informed consent. Participant confidentiality and anonymity were maintained throughout all stages of the research process, and all data were handled in compliance with applicable ethical guidelines.

7.6. Use of Artificial Intelligence (AI) Tools

The author declares that no AI-assisted tools were used at any stage of the preparation of this manuscript, including writing, data analysis, or figure generation. All content is the sole intellectual work of the author.

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