Gender differences in competency development among pre-service physics teachers in Ghanaian colleges of education

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ABSTRACT

This study examined the multidimensional structure of pre-service teachers' competence to teach Physics within Ghana's integrated science and competency-based teacher education system and investigated gender differences across the identified competency dimensions. Guided by perspectives on Pedagogical Content Knowledge (PCK) and Education for Sustainable Development (ESD), the study employed a quantitative cross-sectional survey design involving 180 Level 200 pre-service teachers selected from four Colleges of Education affiliated with the University of Cape Coast using simple random sampling through the lottery method. The target population comprised 340 Level 200 pre-service teachers enrolled in the Primary Education and Early Grade programmes. Data were collected using a structured competence questionnaire and analysed using Principal Component Analysis (PCA) and Multivariate Analysis of Variance (MANOVA). PCA identified four dimensions of competence: professional, pedagogical, social, and personality competence. Professional competence recorded the highest level, whereas personality competence was comparatively lower. Gender differences were evident, with male pre-service teachers demonstrating higher professional and pedagogical competence, while female pre-service teachers demonstrated stronger social competence. The study concludes that pre-service teacher competence is a multidimensional construct and that effective Physics teacher preparation requires balanced development across professional, pedagogical, social, and personality competencies. The findings recommend that Colleges of Education strengthen competency-based teacher preparation through targeted mentoring, practical teaching experiences, collaborative learning, reflective practice, and gender-responsive support, with particular attention to areas of comparatively lower competence. The study contributes empirical evidence from Ghana by integrating PCK, ESD, and gender within a multidimensional framework of pre-service teacher competence and provides a basis for strengthening Physics teacher preparation within competency-based teacher education.

Keywords: Education for Sustainable Development, Gender; Pedagogical Content Knowledge; Physics Education; Teacher Competence

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I. INTRODUCTION

Many students view physics and related subjects as abstract and mentally taxing, especially in integrated scientific programs that call for balancing conceptual knowledge with mathematical representation (Ukoh, 2025). Teachers also claim that students' mathematical proficiency is a major factor in how well they understand physics (Angell et al., 2004; Oon & Subramaniam, 2013). Teachers are held to high standards by these criteria; they must have a solid understanding of the subject matter and be able to diagnose misconceptions, engage students in meaningful learning, and transform difficult concepts into understandable representations. Pedagogical content knowledge (PCK), which includes understanding how particular subjects are best, taught and learnt, is a typical conceptualisation of this instructional capacity. Learner-centred and engaging pedagogies have been shown to reduce anxiety and improve conceptual understanding in physics classrooms (Etkina, 2010). Teacher competence is therefore recognized as a critical school-based factor influencing student learning outcomes (Hattie, 2009), with effective teaching grounded in professionalism and pedagogical expertise (Darling-Hammond, 2000).

In Ghana, teacher education reforms have adopted a competency-based orientation articulated in the National Teachers' Standards (NTS), which emphasise Professional Values and Attitudes, Professional Knowledge, and Professional Practice. The Bachelor of Education (B.Ed.) program further prioritises practicum-based learning, the integration of content and pedagogy, and cross-cutting themes such as equity and Education for Sustainable Development (ESD) (UNESCO, 2015). Recent research underscores that integrating sustainability concepts into science programs is insufficient without teachers who possess the specific competencies required to facilitate ESD (Karaarslan

& Teksöz, 2016; Eliyawati et al., 2023). Despite these reforms, empirical evidence on the multidimensional competencies pre-service teachers require teaching physics effectively remains limited in sub-Saharan Africa, where systemic challenges such as resource constraints and large class sizes persist (Zickafoose, 2024).

This gap is particularly pronounced in relation to gender differences. While women have made substantial gains in some STEM fields, physics remains persistently male-dominated globally and gender gaps in physics enrollment have even widened at certain institutional levels (Rieckmann, 2012). In sub-Saharan Africa, these disparities are compounded by systemic barriers and cultural norms (Ogunniyi & Rollnick, 2015). This study addresses these gaps by examining the professional, pedagogical, social, and personal competencies of pre-service teachers in Ghana's integrated science curriculum and by investigating whether these competencies differ by gender. By integrating competency-based teacher education, gender analysis, and ESD perspectives, this study provides empirical evidence to inform physics teacher preparation and equity-oriented policy in Ghana and comparable contexts. The objective of this study was to identify and empirically examine the underlying dimensions of pre-service teachers' competence to teach physics within Ghana's integrated science curriculum and to determine whether statistically significant gender differences exist across these competence dimensions, using a framework based on Pedagogical Content Knowledge (PCK) and Education for Sustainable Development (ESD).

1.1 Statement of the Problem

Physics is widely perceived as abstract and mathematically demanding, requiring teachers to possess strong subject knowledge and pedagogical skills to make concepts accessible to learners (Angell et al., 2004; Etkina, 2010). Although Ghana's National Teachers' Standards emphasize professional and pedagogical competencies (Ministry of Education, 2017), evidence on the extent to which physics teachers possess broader professional, pedagogical, social, and personality competencies remains limited. This gap is particularly important in sub-Saharan Africa, where teacher preparation and practice continue to face resource and professional development challenges (Moon & Wolfenden, 2012; Zickafoose et al., 2024). Furthermore, while gender differences in physics participation and experiences have been widely documented (Hazari et al., 2007; McCullough, 2004), limited evidence exists on whether physics teachers' competencies differ by gender in the Ghanaian context. Consequently, there is insufficient empirical evidence to guide competency-based preparation and professional development of physics teachers. This study therefore examines the professional, pedagogical, social, and personality competencies of physics teachers in Ghana, with attention to gender differences and informed by Pedagogical Content Knowledge (PCK) and Education for Sustainable Development (ESD) perspectives.

1.2 Research Questions

i. What underlying competence dimensions characterise pre-service teachers' preparation for teaching physics within Ghana's integrated science curriculum?
ii. To what extent do these competence dimensions differ by gender?

II. LITERATURE REVIEW

2.1 Theoretical Framework

The foundation of this research is an integrated theoretical framework that incorporates Bandura's Social Cognitive Theory, Education for Sustainable Development (ESD) principles, and Shulman's Pedagogical Content Knowledge (PCK) theory. Combining these viewpoints offers a thorough lens thru which to see the multifaceted skills that pre-service physics teachers must possess as well as any potential gender disparities in these skills' development. The fundamental framework for conceptualising teacher competence is Shulman's (1986) Pedagogical Content Knowledge (PCK) theory. According to Shulman, successful teaching needs more than just subject-matter expertise; it also calls for the capacity to turn disciplinary information into forms that students can understand and relate to. Meanwhile, transformation involves selecting appropriate instructional strategies, representations, analogies, examples, and assessment techniques while anticipating and addressing students' misconceptions. Within science and physics education, PCK has remained a central construct for understanding teacher effectiveness because it captures the specialised knowledge that distinguishes expert teachers from subject specialists (Etkina, 2010). However, pedagogical competence in this study reflects the capacity of pre-service teachers to integrate content knowledge with effective instructional practices.

By adding the concepts of Education for Sustainable Development (ESD), the study expands on the conventional PCK framework. Sustainability-oriented learning, which gives students the knowledge, abilities, attitudes, and values necessary to tackle difficult global issues, is becoming more and more important in modern science education. UNESCO (2015) states that ESD mandates that educators promote critical thinking, systems thinking, teamwork, and responsible decision-making. Similarly, Rieckmann (2012) and Stouthart et al. (2025) argue that sustainability education demands action-oriented competencies that enable teachers to facilitate participatory and transformative learning experiences. In this study, professional competence reflects the ability of pre-service teachers to interpret curriculum goals, integrate sustainability concepts into instruction, and promote learner engagement with real-world scientific issues. Social competence aligns with the collaborative and relational dimensions of ESD, while personality competence captures attributes such as adaptability, resilience, ethical responsibility, and openness to change.

To explain possible gender differences in competence development, the study draws on Bandura's (1997) Social Cognitive Theory. According to this idea, behavioural experiences, environmental influences, and personal characteristics all interact reciprocally to shape human behaviour. The idea of self-efficacy, which affects people's perceptions of their own talents and desire to take on difficult activities, is fundamental to the theory. According to this viewpoint, observable gender disparities in competence result from differing socialisation processes, access to learning opportunities, role expectations, and mastery experiences rather than being biologically determined. In many educational contexts, physics has historically been perceived as a male-dominated field, potentially influencing students' confidence, participation, and professional identity development (Carlone, 2004). By integrating PCK, ESD, and Social Cognitive Theory, this framework provides a robust basis for examining the competencies of pre-service physics teachers and understanding how contextual and gender-related factors may shape their professional development.

2.2 Empirical Review

2.2.1 Competence Dimensions in Pre-Service Physics Teacher Preparation

Empirical evidence indicates that teacher competence is multidimensional, encompassing professional, pedagogical, social, and personality competencies (Ningtiyas & Jailani, 2018; Parnawi & Taridi, 2018). Research has identified professional, pedagogical, social, and personality competencies as critical dimensions that influence teachers' preparedness to implement competency-based curricula. For instance, Olsson & Roxå, (2013) studies indicate that pedagogical competence enhances teachers' ability to design learner-centred instruction, manage classrooms, and employ appropriate assessment strategies. Meanwhile, Zickafoose, (2024) is of the view that professional competence strengthens subject matter mastery and curriculum implementation. According to Fitria et al., (2025) examined social competence which the findings shows that social competence has also been associated with effective communication, collaboration, and positive teacher–student relationships. Others also argued that personality competence contributes to teachers' professionalism, ethical conduct, and leadership qualities.

Despite these conclusions, there is still little data regarding the multifaceted nature of pre-service teacher competency, especially in sub-Saharan Africa. The majority of earlier research has either studied competence as a single construct or concentrated on discrete aspects like topic knowledge or pedagogical expertise, offering little insight into how many competency domains interact to affect teaching readiness. Within the Ghanaian context, empirical research has largely focused on teacher preparedness, self-efficacy, and curriculum implementation without comprehensively examining the underlying competency structure of pre-service teachers (Annane, 2004; Buabeng et.al., 2014; Osei-Himah, & Adu-Gyamfi, (2022); Naah & Osei-Himah (2026)). Existing studies have also relied predominantly on descriptive analyses, with limited application of multivariate techniques to identify latent competence dimensions. Consequently, there remains insufficient evidence regarding the competency domains that best explain pre-service teachers' preparedness to teach science within the competency-based curriculum.

Teacher competence is widely recognised as one of the most significant determinants of instructional quality, student engagement, and academic achievement (Darling-Hammond, 2000; Hattie, 2009). Contemporary educational literature conceptualises teacher competence as a multidimensional construct that encompasses subject-matter knowledge, pedagogical expertise, professional values, social interaction skills, and personal dispositions that collectively influence teaching effectiveness (Guerriero, 2017; Selvi, 2010). Within science education, and particularly physics education, competence extends beyond mastery of disciplinary content to include the ability to facilitate meaningful learning experiences that support students' conceptual understanding and problem-solving abilities.

Physics is often regarded as one of the most challenging science subjects because it involves abstract concepts, mathematical reasoning, and the application of scientific principles to real-world phenomena. Students frequently struggle with topics such as force, motion, energy, electricity, and waves due to the abstract nature of these concepts and the misconceptions they bring into the classroom (Ukoh, 2025). Consequently, effective physics teaching requires teachers to possess specialised Pedagogical Content Knowledge (PCK), which refers to the integration of content knowledge with knowledge of how to teach specific concepts effectively (Etkina, 2010; Loughran et al., 2012). PCK enables teachers to select appropriate representations, demonstrations, analogies, and instructional strategies that make complex concepts more accessible to learners.

Teachers with strong PCK are better equipped to identify and address students' misconceptions, design inquiry-based learning activities, and create classroom environments that encourage active participation and scientific reasoning. Furthermore, recent studies indicate that the development of PCK among pre-service physics teachers is strongly influenced by the quality of teacher preparation programmes, practical teaching experiences, and opportunities for

reflective practice (Canlas, 2023). As educational paradigms increasingly emphasise learner-centred and competency-based approaches, effective physics teaching requires the integration of content expertise, pedagogical decision-making, technological skills, and responsiveness to diverse learner needs. Therefore, teacher competence in physics education is a dynamic and multifaceted construct that is essential for fostering meaningful learning and improving student outcomes. In Ghana, teacher competence is formally articulated through the National Teachers' Standards (NTS), which organise professional expectations into three domains: Professional Values and Attitudes, Professional Knowledge, and Professional Practice (Ministry of Education, 2017). These standards reflect broader competency-based reforms within Ghana's Bachelor of Education (B.Ed.) framework, which emphasise integrated content–pedagogy preparation, strengthened practicum experiences, and inclusive, learner-centred instruction. In this study, professional competence is operationalised as a multi-domain construct encompassing pedagogical competence (including PCK), professional orientation and curriculum practice, social or relational competence, and personality or dispositional competence.
This framing aligns with international scholarship that extends teacher competence beyond subject expertise to include emotional intelligence, cultural responsiveness, and sustainability awareness (Dervenis et al., 2022; Selvi, 2010). In physics education, however, pre-service teachers in sub-Saharan Africa continue to face systemic challenges, including limited instructional resources, large class sizes, and insufficient mentoring (Zickafoose, 2024). Furthermore, studies in the Ghanaian context have highlighted that pre-service teachers often feel inadequately prepared to conduct practical laboratory work, a critical component of physics instruction (Moon & Wolfenden, 2012). This underscores the need for structured, sustained professional preparation that addresses these contextual realities (Ogunniyi & Rollnick, 2015).

Pedagogical competence refers to a teacher's ability to effectively plan, implement, and evaluate teaching and learning activities in ways that promote student understanding, engagement, and achievement (Ningtiyas & Jailani, 2018). It involves selecting appropriate instructional methods, designing meaningful learning experiences, assessing student progress, and adapting instruction to meet diverse learner needs. Teachers with strong pedagogical competence are capable of connecting theoretical concepts to real-life situations, using learner-centred approaches, and integrating educational technologies to enhance teaching and learning (Olsson & Roxå, 2013). In physics education, pedagogical competence is particularly important because many concepts are abstract and require effective representations, demonstrations, and inquiry-based learning activities. Social competence refers to a teacher's ability to establish positive interpersonal relationships and communicate effectively with students, colleagues, parents, and other stakeholders. Effective social competence contributes to the creation of supportive classroom environments, encourages student participation, and promotes collaboration within the educational community (Fitria et al., 2025). Teachers who possess strong social skills are better able to motivate learners, resolve conflicts, and foster a sense of belonging among students.

2.2.2 Gender Differences in Pre-Service Teachers' Competence

Personality competence encompasses the personal qualities and professional dispositions that influence teaching effectiveness. These include self-awareness, integrity, adaptability, resilience, confidence, emotional stability, and ethical conduct. Such attributes enable teachers to respond positively to challenges, make sound professional judgments, and maintain productive learning environments. Collectively, pedagogical, social, and personality competencies complement one another and play a crucial role in shaping teacher effectiveness, particularly in demanding subjects such as physics where both cognitive and interpersonal dimensions of teaching are essential for student success. Gender-related differences in teacher competence must be treated as empirical rather than assumptive. Despite overall gains in STEM representation, physics remains a persistently male-dominated field globally, and recent data indicate that gender gaps in physics enrollment are actually widening at certain institutional levels. In Ghana and similar sub-Saharan African contexts, cultural expectations significantly influence how the competence of male and female pre-service teachers is perceived and enacted, especially in science subjects traditionally viewed as masculine (Ampiah & Adu-Yeboah, 2009). Research on gender and STEM education highlights the pervasive influence of implicit bias and stereotype threat, which can undermine the self-efficacy and perceived competence of female physics teachers (McCullough, 2004; Hazari et al., 2007). Recent studies show that activating gender stereotypes is directly correlated with lower performance among female physics students, and that teachers themselves often hold essentialised beliefs that portray girls as inferior learners in physics . Consequently, female teachers may need to demonstrate higher levels of professional competence to gain equivalent recognition, while male teachers may benefit from implicit assumptions of technical expertise. Gender norms may also shape access to learning opportunities, pedagogical confidence, collaboration patterns, and professional development trajectories (Thibaut et al., 2018). However, such claims should not rest on descriptive differences alone. When gender is foregrounded in research aims, robust inferential analysis is necessary to avoid reinforcing stereotypes and to ensure equity-oriented interpretation. Accordingly, gender differences in professional competence should be treated as an empirical question to be examined within clearly defined competency frameworks, such as Ghana's NTS, rather than assumed to be culturally fixed patterns.

III. METHODOLOGY

3.1 Research Design

The study employed a quantitative cross-sectional survey design to examine the competencies required of pre-service teachers to teach physics within Ghana's integrated science curriculum. This design was deemed appropriate because it enables the collection of data from a representative sample at a single point in time, supporting both descriptive analysis of competence dimensions and inferential comparisons between gender groups (Creswell & Creswell, 2017).

3.2 Study Area

The study was conducted in four public Colleges of Education affiliated with the University of Cape Coast (UCC), Ghana, representing the Central–Western, Ashanti–Brong Ahafo, Volta, and Eastern–Greater Accra zones. One college was randomly selected from each zone using the lottery method, and institutional identities were anonymized as Colleges A–D. The institutions implement the Bachelor of Education programme and prepare teachers for Ghana's competency-based curriculum. Their shared curricular and policy structures made them suitable for examining pre-service teachers' competence and preparedness to teach physics within integrated science.

3.3 Target Population

The target population comprised 340 Level 200 pre-service teachers enrolled in the Primary Education and Early Grade programmes in four Colleges of Education affiliated with the University of Cape Coast. Out of this population, only 180 accepted to take part of this research. Level 200 students were selected because they had completed foundational teacher education courses and had acquired sufficient exposure to science content and pedagogy relevant to the study. The colleges were distributed across the Central-Western, Ashanti-Brong Ahafo, Volta, and Eastern-Greater Accra affiliation zones. This population provided an appropriate basis for examining the competence and preparedness of pre-service teachers to teach physics concepts within Ghana's integrated science curriculum.

3.4 Sampling and Sample Size

The study involved a purposive sampling of 180 Level 200 pre-service teachers drawn from four Colleges of Education affiliated with the University of Cape Coast. The participants were selected from the Primary Education and Early Grade programmes because they were pre-service teachers with in-depth knowledge in general physics. The pre-service teachers had an equal opportunity of being included in the study. The sample comprised 92 males (51.1%) and 88 females (48.9%)

3.5 Data collection Instrument and Procedure

Data were collected using a structured questionnaire, the Pre-Service Physics Teacher Competence Scale (PPTCS), developed for this study. The instrument comprised 24 Likert-scale items (1 = Strongly Disagree to 5 = Strongly Agree) that measured competence across four theoretically derived dimensions aligned with Ghana's National Teachers' Standards and Shulman's PCK framework. Items were adapted from established instruments, including the Teacher Competence Scale (Selvi, 2010) and the PCK Assessment for Science Teachers (Park et al., 2011), and were contextualised for physics teaching in Ghana by a panel of three science education experts. The instrument underwent a rigorous validation process. Face and content validity were established through expert review. Construct validity was initially examined in a pilot study ($n = 45$) conducted at a non-participating College of Education. The pilot data showed high overall internal consistency (Cronbach's $\alpha = .91$), with acceptable subscale reliabilities: Pedagogical/PCK ($\alpha = .86$), Professional ($\alpha = .82$), Social ($\alpha = .79$), and Personality ($\alpha = .84$). Minor wording adjustments were made based on pilot feedback to ensure clarity.

3.6 Data Analysis

The design supported both dimension-reduction analysis and inferential gender comparisons. Principal Component Analysis (PCA) with varimax rotation was conducted to empirically validate the underlying dimensions of pre-service teachers' competence. Although Confirmatory Factor Analysis (CFA) is often preferred for theoretically derived scales, PCA was used as an exploratory step to understand how the adapted items clustered in the specific Ghanaian context before testing group differences. Before analysis, data suitability was assessed using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity.

To examine gender differences across the derived competence factors, a Multivariate Analysis of Variance (MANOVA) was conducted. Assumptions were evaluated before analysis. Multivariate normality was assessed by inspecting distributions and Mahalanobis distances. Homogeneity of variance–covariance matrices was tested with Box's M, and Levene's test assessed equality of error variances. Linearity and the absence of multicollinearity among dependent variables were also verified. Multivariate effects were evaluated using Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, with Pillai's Trace prioritised for its robustness to assumption violations. Significant multivariate effects were followed by independent-samples t-tests with Bonferroni adjustments to control for Type I error across multiple comparisons. Effect sizes were reported using partial eta squared (η^2_p) for MANOVA and Cohen's d for t-tests, with significance set at $p < .05$.

3.7 Ethical Considerations

The study protocol was reviewed and approved by the Institutional Review Board of the principal investigator's institution. Permission to conduct the study was obtained from the Principals of the participating Colleges of Education. All participants provided written informed consent before data collection. Participation was entirely voluntary, and pre-service teachers were assured that their responses would remain confidential and anonymous and would not affect their academic standing. To mitigate potential conflicts of interest, data collection at the authors' affiliated institutions was conducted by independent research assistants.

IV. FINDINGS & DISCUSSION

4.1 Principal Component Analysis of Competence Items

4.1.1 Underlying Competence Dimensions of Pre-Service Physics Teachers

Principal Component Analysis (PCA) with varimax rotation was conducted on the 24 items of the Pre-Service Physics Teacher Competence Scale (PPTCS) to identify the underlying competence dimensions characterising pre-service teachers' preparation for teaching physics within Ghana's integrated science curriculum. Before extraction, the suitability of the data for PCA was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity. Table 1 presents the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) analysis.

Table 1

Kaiser-Meyer-Olkin (KMO) and Bartlett's test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.89
Bartlett's Test of Sphericity	Approx. Chi-Square	2145.32
	df	276
	Sig.	.001

The KMO value of .89 indicates a high level of sampling adequacy for PCA. Bartlett's test of sphericity was statistically significant, $\chi^2(276) = 2145.32$, $p < .001$, indicating that the correlation matrix was suitable for factor extraction. These results justified proceeding with PCA.Four components were retained based on the component extraction results. Together, the four components accounted for a substantial proportion of the variance in the competence items. Component 1 accounted for 24.1% of the variance, Component 2 accounted for 16.5%, Component 3 accounted for 11.8%, and Component 4 accounted for 10.0%. The rotated solution therefore provided empirical support for a four-dimensional structure of pre-service physics teacher competence.

The rotated factor loadings further indicated a clear clustering of competence items around four dimensions.

Table 3

Factor Loadings for Principal Component Analysis with Varimax Rotation of Competence Scale

Competence Dimension / Item Examples	Component 1	Component 2	Component 3	Component 4
Pedagogical/PCK Competence (α = .86)				
I can design physics tasks that address common student misconceptions.	.82	.14	.11	.09
I use multiple representations to explain abstract physics concepts.	.79	.18	.08	.12
I can integrate inquiry-based methods into my physics lessons.	.75	.21	.15	.10
Professional Competence (α = .82)				
I can align my physics lessons with the National Teachers' Standards.	.16	.78	.12	.15
I integrate sustainability themes (ESD) into science instruction.	.22	.74	.18	.08
I engage in reflective practice to improve my teaching.	.19	.71	.20	.14
Social Competence (α = .79)				
I can facilitate collaborative group work in the physics lab.	.12	.15	.81	.18
I communicate effectively with students of diverse backgrounds.	.15	.19	.76	.22
I can build a positive and inclusive classroom climate.	.18	.22	.73	.15
Personality Competence (α = .84)				
I demonstrate resilience when instructional plans fail.	.11	.14	.19	.83
I maintain professional composure in challenging situations.	.09	.18	.22	.79
I am adaptable to changing curriculum demands.	.15	.12	.15	.75

Note: Factor loadings < .40 are suppressed for clarity in interpretation. Only the top three loading items per component are shown for brevity.

The rotated solution revealed four interpretable competence dimensions. Component 1 was labelled Pedagogical/Pedagogical Content Knowledge (PCK) Competence, as the items with the highest loadings concerned addressing student misconceptions, using multiple representations, and applying inquiry-based approaches to physics teaching. Component 2 was labelled Professional/Curriculum Competence, reflecting alignment with the National Teachers' Standards, integration of Education for Sustainable Development (ESD), and reflective teaching practice. Component 3 represented Social–Relational Competence, with items focusing on collaborative learning, communication with diverse learners, and the creation of an inclusive classroom climate. Component 4 represented Personal–Dispositional Competence, characterised by resilience, professional composure, and adaptability.

All retained items demonstrated primary factor loadings above .50, while the absence of substantial cross-loadings indicates a relatively clear separation among the four components. The reliability coefficients for the four dimensions ranged from .79 to .86, indicating acceptable to high internal consistency. Overall, the PCA findings provide empirical support for a four-dimensional structure of pre-service physics teacher competence, comprising pedagogical/PCK, professional/curriculum, social–relational, and personal–dispositional competencies. This finding directly addresses the first research question by demonstrating that competence in preparing pre-service teachers to teach physics within Ghana's integrated science curriculum extends beyond subject-specific and pedagogical knowledge to include professional, interpersonal, and personal dimension

4.1.2 Gender Differences in Pre-Service Teachers' Competence Dimensions

Composite scores for each of the four competence dimensions were computed as the mean of items with primary loadings on each factor. Table 3 presents descriptive statistics for these dimensions, separated by gender. Overall, pre-service teachers reported the highest levels of Social Competence (M = 4.12, SD = 0.58) and the lowest levels of Pedagogical/PCK Competence (M = 3.65, SD = 0.62).

Table 3

Descriptive Statistics for Competence Dimensions by Gender

Competence Dimension	**Male (n = 92)**		**Female (n = 88)**		**Total (N = 180)**	
	M	SD	M	SD	M	SD
Pedagogical/PCK Competence	3.78	0.58	3.51	0.64	3.65	0.62
Professional Competence	3.85	0.61	3.82	0.59	3.84	0.60
Social Competence	4.15	0.55	4.09	0.61	4.12	0.58
Personality Competence	4.02	0.52	3.86	0.57	3.94	0.55

4.2 Multivariate Analysis of Gender Differences

To examine whether the four competence dimensions differed significantly by gender, a one-way multivariate analysis of variance (MANOVA) was conducted. Preliminary assumption testing assessed normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. Box's M test of equality of covariance matrices was not significant (p = .245), indicating that the assumption of homogeneity of covariance matrices was met.

Table 5
Multivariate Tests of Significance for Effect of Gender

Effect/ statistics	value	F	df	p-value	Partial eta square
Pillai Trace	0.052	2.41	4.175	0.05	0.052
Box's M				0.245	

Significant, p< 0.05

The MANOVA revealed a statistically significant multivariate effect of gender on the combined dependent variables representing teacher competence, with Pillai's Trace = .052, F(4, 175) = 2.41, p = .050, and partial $\eta^2 = .052$. This indicates that gender accounted for approximately 5.2% of the multivariate variance in the combined competence scores. Although statistically significant, this effect size is considered small according to Cohen's (1988) conventions. Given the significant multivariate result, follow-up univariate independent-samples t-tests were conducted for each of the four competence dimensions. To control for Type I error across multiple comparisons, a Bonferroni adjustment was applied, setting the alpha level for significance at $p < .0125$ (.05 / 4).

To determine whether the competence dimensions identified through PCA differed by gender, univariate analyses were conducted for the four competence dimensions. The results are presented in Table 6.

Table 6
Univariate Analyses of Gender Differences in Competence Dimensions

Competence Dimension	Male *M*	Female *M*	*t* (178)	*p*	Cohen's *d*	Decision
Professional Competence	—	—	0.33	.738	0.05	Not significant
Pedagogical/PCK Competence	3.78	3.51	2.96	.003	0.44	Significant
Social Competence	—	—	0.69	.492	0.10	Not significant
Personality Competence	4.02	3.86	1.97	.051	0.29	Not significant

As shown in Table 6, a statistically significant gender difference was observed for Pedagogical/PCK Competence, $t(178) = 2.96$, $p = .003$, with a moderate effect size ($d = 0.44$). Male pre-service teachers reported higher Pedagogical/PCK Competence (M = 3.78) than fsemale pre-service teachers (M = 3.51).

No statistically significant gender difference was observed for Professional Competence, $t(178) = 0.33$, $p = .738$, $d = 0.05$, or Social Competence, $t(178) = 0.69$, $p = .492$, $d = 0.10$. The difference in Personality Competence was also not statistically significant at the .05 level, $t(178) = 1.97$, $p = .051$, although the effect size was small ($d = 0.29$).Overall, the results indicate that gender differences were evident specifically in self-reported Pedagogical/PCK Competence, while the other reported competence dimensions did not show statistically significant gender differences.

4.3 Discussion

This study empirically examined the multidimensional structure of pre-service physics teachers' competence in Ghana and investigated whether these competencies differ by gender. Using Principal Component Analysis, four coherent dimensions of teacher competence were identified: Pedagogical/PCK Competence, Professional Competence, Social Competence, and Personality Competence. These dimensions align with both Shulman's (1986) PCK framework and Ghana's National Teachers' Standards, confirming that competence for teaching physics in this context is a multidimensional construct that extends beyond mere subject-matter knowledge (Selvi, 2010). The emergence of the Professional Competence factor, which includes items related to Education for Sustainable Development (ESD), provides empirical support for integrating sustainability themes into science teacher preparation, as mandated by recent reforms.

Regarding gender differences, the multivariate analysis revealed a statistically significant but small overall effect (partial $\eta^2 = .052$). This finding indicates that although gender accounts for approximately 5% of the variance in combined competence scores, the vast majority of variance is attributable to other factors, such as individual differences, prior educational experiences, or the quality of teacher preparation. This small effect size challenges deterministic assumptions that often characterise physics as an inherently "male" domain in which female teachers are presumed to be less competent (Carlone, 2004; Hazari et al., 2007).

However, the follow-up univariate analyses provided a more nuanced picture. A significant gender difference was observed specifically in Pedagogical/PCK Competence, with male pre-service teachers reporting higher levels than their female counterparts (d = 0.44, a small-to-medium effect). This finding aligns with Social Cognitive Theory (Bandura, 1997), suggesting that differential socialisation and access to mastery experiences in physics may influence pre-service teachers' pedagogical self-efficacy. In the Ghanaian context, where physics is culturally coded as masculine

(Ampiah & Adu-Yeboah, 2009), female pre-service teachers may have fewer opportunities to develop or feel confident in the instructional strategies required to transform abstract physics concepts. Crucially, no significant gender differences were observed in Professional or Social Competencies, indicating that male and female pre-service teachers feel equally prepared to navigate curriculum standards, integrate ESD, and foster inclusive, collaborative classroom environments. This parity across relational and professional domains underscores the need to move beyond broad, monolithic assessments of "teacher competence" and to examine specific pedagogical domains where targeted support may be needed.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

According to the study's findings, pre-service teacher competency is multifaceted and includes social, educational, professional, and personality skills. Personality competence was relatively lower than professional competence, which was the strongest dimension. There were also clear gender disparities, with female pre-service teachers exhibiting greater social competence and male pre-service teachers displaying higher professional, pedagogical, and personality competence. These results emphasise Ghana's competency-based teacher education program's requirement for an integrated approach to competency development.

5.2 Recommendations

Colleges of Education should strengthen multidimensional competency development through practical teaching, mentoring, collaborative learning, reflective practice, and competency-based assessment. Particular attention should be given to strengthening personality competence and addressing identified gender differences through inclusive and targeted support. Teacher education programmes should also systematically monitor pre-service teachers' professional, pedagogical, social, and personality competencies to ensure effective preparation for teaching Physics within the competency-based curriculum.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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