

Mathematics Teacher Educators' Geometry Pedagogical Content Knowledge: Pre-service Teachers' Perceptions and Instructional Enactment in Colleges of Education in Ghana

Frank ADU^{1*}, Sylvester Ali FRIMPONG², Theophilus Kwasi KLU³ and Veronica NTIM-MANTEAW⁴

¹Department of Mathematics/ ICT. Abetifi Presbyterian College of Education, P.O. Box 19, Abetifi Kwahu, Eastern Region, Ghana.

²Department of Mathematics. University of Education, Winneba P. O. Box 25, Winneba, Central Region

³Department of Mathematics/ ICT. Abetifi Presbyterian College of Education, P.O. Box 19, Abetifi Kwahu, Eastern Region, Ghana.

⁴Department of Mathematics/ ICT. Kibi Presbyterian College of Education, P. M. B. Kibi, Eastern Region, Ghana.

*Corresponding Author Email: frankadu@abeticoe.edu.gh; 0009-0008-0107-8906; mali@uew.edu.gh; 0000-0002-9340-7859; theo0243@gmail.com; 0000-0001-8219-7262; Vn.manteaw@kpce.edu.gh

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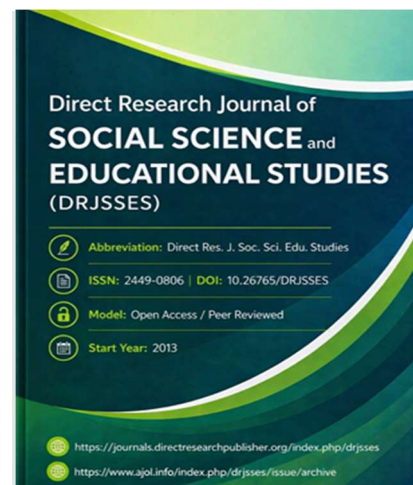
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ABSTRACT

Teaching geometry is challenging as it requires knowledge of content and representations, anticipating possible learner misunderstandings, and knowing how to implement the teaching methods. Not much research exists in examining how mathematics teacher educators (MTEs) show geometry-specific PCK in teacher preparation programs. The study explored PSTs' perceptions of MTEs' geometry pedagogical content knowledge and teaching effectiveness in Colleges of Education in Eastern Ghana. The study was guided by an explanatory sequential mixed-methods design involving a questionnaire administered to a sample of 235 first-year PSTs developed along a five-point Likert scale (1 = strongly disagree). The investigation involved semi-structured interviews and classroom observations of 10 participants. The four PCK components assessed in the questionnaire were content knowledge, knowledge of students' understanding, instructional strategies, and curriculum and assessment knowledge. PSTs rated MTEs as effective geometry instructors overall, with a mean of 3.85 and an SD of 1.08. PSTs rated MTEs' PCK highest for understanding how to connect geometry concepts to the real world ($M = 4.09$, $SD = 0.96$), and understanding how to use multiple representations ($M = 3.95$, $SD = 1.08$). Teaching actions specific to geometry ($M = 3.66$, $SD = 1.04$), and teaching actions focused on addressing student misconceptions ($M = 3.65$, $SD = 1.22$) received lowest averages. Qualitative results indicated PSTs valued explanation, examples, representations, and questioning, but desired pedagogical training on adaptive instruction, manipulatives, and technology integration in particular. Findings confirm the importance of sound mathematics content knowledge and learner-centered pedagogy for effective teaching of geometry, supported through active professional development for MTEs.

Keywords: Pedagogical content knowledge, Mathematics teacher educators, Pre-service teachers, geometry teaching, perceptions, Ghana



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INTRODUCTION

Geometry is one of the strands of the mathematics curriculum. It has been described as an important area of mathematics as it gives the opportunity to develop spatial reasoning, visualization, logical thinking and mathematical argumentation. This can be different from some other areas of mathematics which are more algorithmic. However, students experience difficulties in understanding geometric objects, the relationships among the representations of these geometric objects, and argumentation in geometry (Opus *et al.*, 2025; Duong & Hoan, 2025). Because of these difficulties, the teaching of geometry is complex, so teachers are required to have not only knowledge of geometry but also knowledge of how to teach geometry. Given the challenges of teaching geometry well, mathematics teacher education programs may need to explicitly consider the geometry course(s) and the geometry pedagogical knowledge of pre-service teachers (Hoffmann & Biehler, 2023; Arwadi *et al.*, 2023; Duong & Hoan, 2025; Opus *et al.*, 2025). Similar trends have been found in Ghana, where PSTs' geometry knowledge increased after a mathematical modeling and problem-solving intervention but a PST's knowledge translation of mathematical concepts into the classroom remains a challenge (Agyei & Tettey, 2025). Gaps in how knowledge for teaching geometry is developed and modeled in teacher education have thus been highlighted. Theoretical framework was based upon Shulman's (1986) theory of Pedagogical Content Knowledge (PCK), which requires subject matter understanding and knowledge of how to convert subject matter understanding to a form that students can understand. PCK involves knowledge of students' prior conceptions, learning trajectories, alternative conceptions, representations, explanations, instructional strategies, assessments, and teaching. Thus, teachers not only need mathematical content knowledge, but they need knowledge of how to adapt mathematics and communicate mathematics in ways that will improve student learning. Geometry is often used to investigate PCK because teaching geometry involves mediating supporting diagrams, visualization, spatial reasoning, symbols, formal mathematical reasoning, etc. A teacher develops geometry-specific PCK when they understand how pupils develop geometric understanding, know common pupils' misconceptions in geometry, and know which instructional practices help pupils move from intuitive to formal mathematical understanding. PCK has been well-studied in the context of classroom teachers and PSTs, but not in the context of mathematics teacher educators (MTEs), or those who train prospective mathematics teachers. They must teach about mathematics content while simultaneously enacting the work of the teachers their students want to become. Through explaining and questioning, use of representations and consideration of learners' thinking, MTEs can make the enactment of mathematics teaching visible to their students. Therefore, PSTs learn not only the

mathematics content of methods courses but how MTEs make sense of their students in order to teach mathematics. Building on Shulman's work on PCK, we expand understandings of PCK to focus on the ways in which MTEs enact and model subject-specific PCK as they prepare PSTs to learn to teach. Rather than focusing on PCK mainly as teachers' and PSTs' knowledge, we position PCK as professional knowledge that is modeled, articulated, and developed in practice. As such, it is a central component of MTEs, fostering PSTs' beliefs about good mathematics teaching.

With the introduction of several mathematics educational technologies, the role of technology in mathematics teaching has expanded PCK to include TPACK, short for Technological Pedagogical Content Knowledge, as proposed by Mishra & Koehler (2006) by combining the technological knowledge of mathematics with pedagogical knowledge and content knowledge. The use of tools such as dynamic geometry software in the teaching and learning of geometry can support exploration, visualization and understanding of the mathematics. Teachers need to notice links between the technology, the content, and the pedagogy. Research on PSTs' development of TPACK suggests that technology-rich instruction promotes math learning, although PSTs find intertwining technological, pedagogical, and content knowledge (TPACK) difficult (Namli *et al.*, 2026). While TPACK has implications for mathematics education in the 21st century, this study focuses on PCK to understand how MTEs transform their geometry knowledge into learner-centered instruction. Research has shown that PSTs continue to have trouble developing knowledge for teaching geometry (Opus *et al.*, 2025) and may focus on explanations, demonstrations, examples, and representations in geometry instruction while struggling with student misunderstandings and selecting appropriate instructional strategies for teaching geometry concepts. In line with this, Duong and Hoan (2025) found PSTs with procedural knowledge struggled to design tasks for deeper conceptual understanding.

In Ghana, Colleges of Education train teachers for basic education schools. Research has investigated PSTs' mathematical knowledge, geometry interventions, mathematical modeling, and technology-supported instruction. Despite this, limited research has investigated PSTs' views of geometry PCK of their MTEs or the way MTEs use geometry PCK in their practice. Understanding PSTs' views of MTEs' practice is important, as teacher preparation impacts future teachers' teaching of mathematics. One aspect of geometry PCK examined in the study was modeling capacity, defined as how MTE show mathematical knowledge transformed into decision-making to support learners' understanding in doing mathematics using meaningful representations, diagnosing learners' challenges, effective explanation, purposeful questioning, and modeling reasoning-based pedagogical actions. By examining the practice of MTEs

and PSTs' perceptions of their practice, this study can help explain how MTEs develop and communicate knowledge for teaching geometry in teacher education programmes. Thus, the purpose of this study was to examine pre-service teachers' views on mathematics teacher educators' pedagogical content knowledge (PCK) and the quality of the geometry teaching in the Colleges of Education in Eastern Ghana. To achieve this purpose, the study is guided by the following research questions:

1. How do pre-service teachers perceive mathematics teacher educators' pedagogical content knowledge about teaching geometry?
2. What do pre-service teachers perceive as the strengths and weaknesses in mathematics teacher educators' geometry pedagogical content knowledge?
3. How do mathematics teacher educators use their pedagogical content knowledge to teach geometry?
4. How may pre-service teachers' perceptions and experiences help explain the quantitative findings related to mathematics teacher educators' pedagogical content knowledge of teaching geometry?

METHODOLOGY

Research Paradigm

This study adopts the pragmatist research model because the nature of the research problem required a combination of quantitative and qualitative research to understand PSTs' views of MTEs' PCK and PSTs' experiences of geometry instruction in TE programs. The pragmatist research model posits that the research methods to be used in a study should be determined by the nature of the research problem to be investigated and the type of knowledge to be generated rather than by the researcher's belief in any philosophical model (Morgan, 2014). The pragmatist model was appropriate because the MTEs' geometry PCK represents a construct with concrete dimensions of mathematical knowledge and situated practices. Although quantitative methods identified ways that PSTs viewed MTEs' dimensions of knowledge, such as content, knowledge of students' mathematical understanding, knowledge and use of instructional practices, and knowledge of curriculum and assessment, these methods could not explain how MTEs transformed such knowledge into practices in mathematics classrooms. Thus, qualitative data were necessary to explore the instructional decisions, representations chosen, explanations given, questions asked, and interactions in which geometry PCK was enacted.

Research Design

The study employed an explanatory sequential mixed-methods design consisting of two connected phases: a quantitative phase and a qualitative phase (Creswell &

Plano Clark, 2018). The design was deemed suitable as the study first sought to identify the patterns in PSTs' perceptions of MTEs' geometry PCK and then to explain and contextualize the patterns through the teaching practices of the MTEs. Quantitative data were obtained from PSTs using a questionnaire that involved rating their perceptions of MTEs' geometry PCK in relation to the four domains of geometry PCK: content knowledge, knowledge of students' understanding, knowledge of instructional strategies, and knowledge of curriculum and assessment. It is these ratings that provided perception into the geometry PCK of MTEs, from which an overall picture of strengths and weaknesses was gained. However, PST perceptions alone could not account for how MTEs enacted geometry PCK in practice. As such, the qualitative phase used semi-structured interviews and classroom observations to answer how MTEs represented concepts, handled misconceptions, implemented instructional strategies, used questioning strategies, and promoted reasoning and problem-solving related to geometry. The merging of the two data sets allowed the study to develop a more subtle understanding of the relationship between PST perceptions and observed enacted geometry PCK in teacher education.

Population, sample size, and sampling procedures

The participants in the study were pre-service teachers (PSTs) and mathematics teacher educators (MTEs) selected from some Colleges of Education in the Eastern Region of Ghana. The PSTs, who were the beneficiaries of the mathematics teacher preparation and the teaching practices modeled by MTEs, were included in the study. Their perceptions provided understanding into how the professional knowledge of the MTEs was interpreted in teacher education experiences. MTEs were included because they prepare future mathematics teachers and they model professional practices for math teaching in their classrooms. The sample size for the study was determined using Yamane's (1967) sample size formula.

$$\text{Formula: } n = N / [1 + N(e^2)]$$

Where:

n = required sample size

N = total population size

e = level of precision (sampling error)

Given:

Population size (N) = 350 pre-service teachers (PSTs)

Required N (sample size) = 235 PSTs

Precision level (e) is approximately 3.7%.

Calculation: $n = 350 / [1 + 350(0.037^2)]$

$$0.037^2 = 0.001369$$

$$350 \times 0.001369 = 0.47915$$

$$1 + 0.47915 = 1.47915$$

$$n = 350 / 1.47915$$

$$n = 236.62$$

The final sample count was 235 pre-service teachers, despite the calculations taking rounding into account. The sample size was determined by using Yamane (1967) formula for sample size determination and found to be approximately 235 pre-service teachers of the 350 total population, with a margin of error of approximately 3.7%. This sample size was determined so that the study population would be adequately represented while remaining practical for data collection. The study employed a probability sampling technique of [insert exact sampling method used being probability sampling technique] to sample PSTs in the participating Colleges of Education to ensure representation of the total population of PSTs enabled each PST in Colleges of Education to have an equal sampling chance of participating in the study. For the qualitative phase, for the same reasons that qualitative research needs participants that have experienced the phenomenon under investigation and can report information-richly about the research issue of the study, I used purposive sampling to recruit ten participants. Observations of classrooms were conducted with a total of twelve MTEs who taught mathematics education courses related to geometry. While MTEs did not complete the PST perception questionnaire, they provided data via observations of their instructional practices.

Data Collection Instruments

Table 1 presents the reliability results of the instruments used in collecting the data (questionnaire, a semi-interview guide, and a classroom observation checklist). The target of the questionnaire was to measure PSTs' perceptions of geometry PCK of MTEs on the components: (i) knowledge of content; (ii) knowledge of students' understanding; (iii) knowledge of instructional strategies; and (iv) knowledge of curriculum and assessment. Items were measured on a five-point Likert scale from 1 = Not Effective to 5 = Very Effective. The semi-structured interview guide requested participants' experiences and beliefs about teaching practices for MTE, such as explaining geometric concepts, addressing misconceptions, fostering students' mathematical reasoning, and supporting conceptual understanding.

Table 1: Reliability Statistics of the Pedagogical Content Knowledge (PCK) Scale

Item	If item dropped		
	Mean	SD	Cronbach's α
Content Knowledge	3.90	0.927	0.828
Knowledge of Students' Understanding	3.73	0.993	0.809
Instructional Strategies	3.86	1.000	0.812
Curriculum and Assessment Knowledge	2.83	0.645	0.864

Source: field survey, 2026

To assess the reliability of the PCK scale, a Cronbach's alpha was applied for the four specific PCK dimensions (Table 1). The four dimensions were found to have

acceptable internal consistency (alpha between 0.809 and 0.864). The reliability coefficient for the whole instrument was $\alpha = 0.868$, which indicates that the items are reliably measuring the intended constructs of PCK. The reliability of each of the PCK components was as follows: knowledge of curriculum and assessment $\alpha = 0.864$, knowledge of content of the lesson $\alpha = 0.828$, knowledge of instructional strategies $\alpha = 0.812$, knowledge of learners' understanding $\alpha = 0.809$. These results suggest that the instrument was sufficiently reliable for assessing PSTs' perceptions of MTEs' geometry PCK.

Data Analysis

Quantitative data were coded, cleaned, and analyzed using excel spreadsheet. To analyze PSTs' perceptions of MTEs' geometry PCK, descriptive statistics were computed, including frequencies, percentages, means, and standard deviations. Additionally, the questionnaire's internal reliability was calculated using Cronbach's alpha. Qualitative data from both interviews and classroom observations were analyzed using Braun & Clarke's (2006) thematic analysis method. These steps included: (1) familiarization with the data, (2) generating initial codes, (3) searching for patterns/themes, (4) refining themes, and (5) interpreting themes. The identified themes reflected the aspects of MTEs' attention to geometric concepts, responding to students' conceptual understanding, adapting instruction, and promoting students' mathematically-based reasoning. Interviews were triangulated with classroom observations and qualitative findings were compared with quantitative results to provide credibility.

Ethical Considerations

The study was given ethical approval by the Graduate School Board, University of Education, Winneba. The participants were given information on the purpose, procedures and any risks involved in the study. Participation was voluntary and participants were informed that they could opt out of the study at any stage without consequence. Confidentiality and anonymity were maintained throughout by referencing participants using a code during the data collection, analysis and reporting processes. In order that these data, which represented the observed MTEs and then the PSTs' views of them, be used only for research purposes and not to evaluate PSTs or the institution's performance, precautions were taken.

RESULTS AND DISCUSSION

Demographic Characteristics of Respondents

Table 2 summarizes the demographic data of pre-service teachers (PSTs) and mathematics teacher educators (MTEs) who participated in the research study; it includes

Table 2: Demographics of Respondents of study respondents.

Participant Group	Characteristic	Category	N	%
Pre-service Teachers(n = 235)	Gender	Male	115	49.0
		Female	120	51.0
		Total	235	100
	Age	16-20 year	75	31.9
		21 to 25 years	112	47.7
		Above 25 years	48	20.4
		Total	235	100
Mathematics Teacher	Gender	Male	8	66.7
		Female	4	33.3
Educators (n = 12)	Highest Qualification	Mphil	10	83.3
		PhD	2	16.7
		Total	235	100

Source: Field Survey 2026

gender and age of PSTs and MTEs, as well as the academic qualifications of MTEs. As such, these characteristics may account for PSTs' perceptions of MTEs' PCK, as perceptions of study participants may be influenced by their experience in the education system and context in which they learn. In total, the PST sample is comprised of 235 participants. The sample was balanced by gender, with slightly more female PSTs ($n = 120$, 51.0%) than male PSTs ($n = 115$, 49.0%). The ratio between men and women was almost 1:1, so our results should not have been biased because one gender had more experiences than the other.

The finding was consistent with similar trends in other countries, where increasing numbers of females were entering teacher education, especially in Ghana. This balanced representation is meant to create a more accurate portrayal of PST perceptions by including male and female perspectives. The PSTs were of a young age group, with 112 (47.7%) in the 21 to 25 years age group, 75 (31.9%) in the 16 to 20 years age group and 48 (20.4%) above the age of 25 years. This distribution fits with the age profile of a cohort of teacher trainees in Colleges of Education although, due to the inclusion of older students, some variation in educational experiences may have affected perceived mathematics teaching practices.

Out of 12 MTEs, 8 (66.7%) were males and the remaining 4 (33.3%) were females. The educational qualifications of MTEs were MPhil (83.3%, $n = 10$) and PhD (16.7%, $n = 2$). The high proportion of MTEs with postgraduate qualifications indicates the participants' high level of academic qualifications in mathematics teacher education. Academic qualifications per se are not an indication of effective pedagogy. The teaching of mathematics is made possible by the transformation of mathematics knowledge into PCK to support students' learning experiences (Shulman, 1986). This is a suitable population context to study geometry PCK, as the combination of PSTs' perspectives and experiences of MTE instruction follows the argument of teacher learning as dependent on both programs of preparation and situated learning in the classroom context (Shulman, 1986; Osiakwan *et al.*, 2026). It also enables us to examine how geometry teaching knowledge is interpreted, enacted, and expressed in Colleges of Education in Eastern Ghana.

Mathematics Expertise as the Foundation of Effective Geometry Teaching

Table 3 presents the mean scores of PSTs' perceptions on the effectiveness of MTEs' pedagogical content knowledge (PCK) in teaching college geometry. Overall, the pre-service teachers (PSTs) viewed mathematics teacher educators (MTEs) as strong collegiate geometry instructors as evidenced by the PCK average score of 3.85 ($SD = 1.08$). However, PSTs viewed a difference in the four PCK domains between the mathematics expertise of geometry and the pedagogical enactment of geometry in the classroom. MTEs were rated highest on content knowledge. The three highest rated means were: using examples to show the application of geometry concepts ($M = 4.09$, $SD = 0.96$), using examples from simple to complex ($M = 3.97$, $SD = 1.09$), and explaining geometric concepts with different representations ($M = 3.95$, $SD = 1.08$). This suggests that PSTs stressed MTEs that use examples, visualisation, and application to explain abstract geometric concepts. Thus, this study confirmed Shulman's (1986) assertion about the necessity of transforming disciplinary knowledge into student-accessible representations, but indicates that in geometry teacher education, professional mathematical knowledge is a starting, rather than an end, product of successful teaching. Qualitative data indicate how this process transpired: PSTs appreciated MTEs who avoided delivering geometric rules to students, and who instead, re-structured mathematical ideas by using diagrams, systematic approaches, and relatable situations. For example, participants found that MTEs helped them understand generalisations like proofs, transformations, and coordinate geometry by breaking down larger concepts into smaller components. The perceived contribution of MTEs' content knowledge seems to depend on their ability to translate mathematical concepts into meaningful learning experiences for their students. This finding furthers the case for using representations and examples in the teaching of geometry to support student connections to concepts (Opus *et al.*, 2025). This study adds to this literature through its focus on MTEs, which provides information about the existence of this transformation problem at the teacher educator level. Simply put, mathematical depth of knowledge does not guarantee an ability to prepare future teachers to teach Mathematics effectively.

The translation gap between knowing geometry and teaching geometry

The high PST ratings of MTEs notwithstanding, the low rating of considering concept-specific instructional strategies for geometry ($M = 3.66$, $SD = 1.04$) and considering students' misconceptions ($M = 3.65$, $SD = 1.22$) suggest an unduly high consideration of mathematical explanation as opposed to learner-responsive pedagogy.

Table 3: Pre-service teachers' rating of their perception of MTEs PCK effectiveness in teaching college geometry

S/N	A. Content Knowledge	N	Very Effective	Effective	Moderately Effective	Slightly Effective	Not Effective	Mean	Standard deviation
1.	Deliberately sequence geometry examples from simple to complex build conceptual understanding	235	89(38)	85(36)	35(15)	16(7)	10(4)	3.97	1.09
2.	Explaining geometric ideas using multiple representations (visual, symbolic, verbal)	235	94(40)	68(29)	46(20)	22(9)	5(2)	3.95	1.08
3.	Connecting geometry content to real-life and practical applications	235	100(43)	75(32)	43(18)	16(7)	1(0.4)	4.09	.96
B. Knowledge of Students' Understanding									
4	Identifying and addressing students' common misconceptions in geometry	235	70(30)	85(37)	48(20)	20(9)	12(5)	3.77	1.12
5	Adjusting instructional approaches based on students' level of geometric thinking	235	82(35)	77(33)	52(22)	22(9)	2(0.9)	3.91	1.01
6	Using effective questioning techniques to probe students' understanding of geometry concepts	235	79(34)	78(33)	52(22)	20(9)	6(3)	3.87	1.06
C. Knowledge of Instructional Strategies									
7	Using appropriate teaching methods to explain abstract geometric concepts	235	81(35)	80(34)	41(17)	23(10)	10(4)	3.85	1.13
8	Incorporating visual and manipulative tools to enhance geometric understanding	235	89(38)	63(27)	54(23)	17(7)	12(5)	3.85	1.16
9	Employing collaborative/group activities to facilitate active learning in geometry	235	92(39)	70(30)	34(15)	18(8)	21(9)	3.83	1.27
Curriculum and Assessment Knowledge									
10	Effectively interpreting and implementing the College of Education geometry curriculum	235	81(35)	65(28)	56(24)	26(11)	7(3)	3.80	1.12
11	Effectively Develop instructional strategies tailored to teaching geometry.	235	53(23)	89(36)	61(26)	25(11)	7(3)	3.66	1.04
12	Effectively know how to address students' common misconceptions in geometry.	235	74(32)	62(26)	58(25)	25(11)	16(7)	3.65	1.22
Overall Mean PCK								3.85	1.08

Source: Field study, 2026

This may be theoretically important, as PCK is not only the possession of mathematical knowledge, but also knowing how students think, where they encounter difficulties, and how to guide them through the development of concepts. The present results suggest that MTEs may do a better job of showing what mathematics is than of modelling how mathematics learning develops. This may be especially true for geometry, where learners' difficulties often appear to arise from misconceptions, poor visual reasoning, and understanding the representation-abstract structure relationship. This was shown through the quantitative data, as learner-centred dimensions were generally below the scores for content knowledge, indicating different

trajectories for knowledge of Mathematics and pedagogical responsiveness. This study contributes to prior research indicating pre-service teachers may be able to solve mathematical problems yet fail to interpret student reasoning, select appropriate representations, and predict potential student errors (Duong & Hoan, 2025; Opus *et al.*, 2025). This study also adds to the understanding this is not just a PST issue, but is also important for MTE professional development. Consequently, mathematics teacher education (MTE) must move beyond developing MTEs' content knowledge to focus on pedagogies that enable MTEs to model diagnostic, adaptive, and learner-responsive interactions.

Understanding Learners' Thinking and Addressing Misconceptions

PSTs understood several aspects of student learning, echoed in the findings that learner-centred PCK was seen as an important aspect of their MTE. PSTs had positive views towards MTEs; qualitative data indicated that PSTs appreciated lecturers anticipating learners' misconceptions and implementing strategies to counteract conceptual difficulties. MTEs also covered information on the difference between perimeter and area, properties of parallel lines, and angle relationships, all of which were deemed common misconceptions. For example, teaching students to manipulate the angles within a triangle to conclude that they sum to 180 degrees shows that PCK involves designing learning experiences that help students make sense of mathematics, distinguishing it from knowing the answer from knowing how to support students in their reasoning. This finding can be used to support Shulman (1986) that teachers need to know about their learners' difficulties and representations. It can also provide a support to Kosko *et al.* (2026) that noticing learners' mathematical thinking is related to the development of professional knowledge. This can imply a need for more attention in MTE professional development in diagnosing mathematical thinking and responding to learner responses and assessment results using appropriate instructional interventions.

Modelling Learner-Centred Instruction and Technology Integration

The qualitative data suggest that PSTs consider the quality of MTE by the lecturer's teaching of certain pedagogical strategies in the MTE course: group work, questioning, problem-solving activities, and discussion of mathematical thinking. PSTs may consider these pedagogical strategies meaningful because there is evidence that PSTs learn how to teach mathematics by observing how their teacher educators teach in teaching courses. However, PSTs did not always report the modelling of learner-centred pedagogies through their perception of a lack of manipulative materials, technology for teaching, and modelling of interactive teaching. This finding suggests that despite possessing strong mathematical knowledge, MTEs require further support in modelling contemporary geometry pedagogy strategies. For example, the TPACK framework (Mishra & Koehler, 2006) states that technology integration is about the interplay of technological knowledge, mathematical knowledge and pedagogical knowledge and not just about having technology. Supporting this, other research has indicated that while PSTs benefit from geometry with technology, they find it difficult to integrate technology with pedagogy and content knowledge (Namli *et al.*, 2026). Therefore, technology integration into mathematics teacher education should entail ensuring MTEs have access to technology and also

experiences that allow MTEs to understand how they can use technology to reason, visualise, and conceptualise.

Pre-service Teachers' Perceptions of MTEs' PCK in Teaching Geometry: A Qualitative Analysis

To examine the quantitative results of MTEs' PCK against participants' lived experiences of MTEs, qualitative data were collected via interviews and classroom observations, and analysed using thematic analysis. The data was found to corroborate the quantitative analysis, as the PSTs also generally perceived MTEs as teaching the College Geometry content well. The qualitative evidence presented rich information regarding the teaching methods, involved in MTEs' demonstrations of their PCK. PSTs appreciated the MTEs' mathematical knowledge and methods of portraying abstract mathematical knowledge of the topics via sequencing, representation, contextualization and addressing misconceptions, as well as using interactive instructional strategies in their teaching process.

Simplifying Abstract Concepts

PST 1-PS5 suggested that MTEs helped them make sense of abstract geometric topics through the use of sound explanations and multiple representations. Topics in geometry, such as coordinate geometry, transformations, circle theorems, loci, and proofs, were reported as being more abstract and challenging to understand and work with at first. MTEs helped overcome these shortcomings by breaking these ideas down into smaller steps, using pictures and diagrams, and examples. "The PSTs recognised multiple aspects of the MTEs as being positive and one aspect they recognised was the decomposition of complex geometry concepts. Many PSTs thought the geometric concepts were abstract. The PSTs found coordinate geometry, transformations, circle theorems, loci and proofs especially hard but thought the MTEs explained these concepts step-by-step with a diagram and example. The PSTs found the MTEs helped break down each area in an easily understandable way. Thus, they were able to understand each concept".

Participants believed that MTEs were not only about formulas, but also included conceptual understanding. Instead of simply giving formulas, MTEs would show the relationship of the sides of a right-angled triangle in a visual and tactile manner. This made learners understand the logic of the theorem rather than memorizing a formula. This is evidence for PCK in action because MTEs turned abstract mathematics into resources learners could understand, just as Shulman (1986) claimed that teachers need to represent subject matter intelligibly to learners. This is congruent with Opus *et al.* (2025) finding that geometry teachers' examples, illustrations, and representations influenced learners' understanding of the concepts being taught.

Selecting appropriate examples and addressing Student Misconceptions

Finally, *PST6 & PST12* also identified anticipating and addressing misconceptions as another important aspect of effective geometry teaching, citing their lecturers' frequent discussion of common errors and ways of addressing them. *"Some lecturers anticipated the errors students would make and addressed them during lessons. For example, students often became confused about the difference between perimeter and area, as well as the properties of parallel lines and corresponding angles."* Another participant explained: *"When explaining the sum of angles in a triangle, some MTEs encouraged students to draw and cut the triangle angles and place them on a straight line to show that the three angles add up to 180 degrees."*

MTEs used demonstrations and probing questions, not just asking the question or providing the correct answer, to support their students, which indicates that PCK is not just knowing the right answers, but knowing the difficulties students have and how to address them (Shulman, 1986).

Implications for Mathematics Teacher Education

Overall, the study shows that effective MTEs build mathematical knowledge and enable these models to be applied pedagogically. PSTs acknowledged that MTEs have strong mathematics content knowledge. To teach geometry teachers well, MTEs need diagnostic knowledge of teacher misconceptions, adaptive teaching knowledge, knowledge of formative assessment, and knowledge of digital technology. This study extends PCK research by examining the PCK translation gap in mathematics teacher education and arguing that mathematics expertise alone does not make an MTE equipped to prepare pre-service teachers to teach mathematics. To help close the PCK translation gap, MTEs should be supported with professional development that encourages them to reflect on their teaching decisions, analyse their learners' mathematical thinking, and model evidence-based ways of teaching geometry. Thus, mathematics teacher education programmes should stress the importance of MTEs who can enact pedagogically important practices over those who are qualified in terms of the discipline. Such a stance would assist PSTs in viewing geometry not just as a collection of procedures or facts to be memorised and recalled but as a discipline involving reasoning, visualisation, exploration, and concept development.

Conclusion

This study sought to investigate PSTs' perception of the geometry PCK of MTEs and the quality of geometry teaching of the MTEs in the Colleges of Education in the Eastern Region of Ghana.

The results of the study revealed that the geometry teaching of the MTEs is perceived to be effective. However, some differences between dimensions of geometry PCK were found, suggesting that strong mathematics knowledge does not guarantee good pedagogy. MTEs as a group understood subject-matter PCK better, especially in applying multiple representations, contextualizing the geometric ideas and linking them to life situations. They were also believed to have weaker learner-centered PCK for anticipating geometry-specific learner misconceptions, and for deciding on teaching strategies to address learners' difficulties and adapt to learners' prior knowledge or understanding. This section's findings were supported qualitatively, with MTEs using effective teaching methods including visual diagrams, demonstrations, contextualized examples, and questioning strategies to support students' learning of abstract geometric ideas. However, the study's results also highlighted the need to go beyond explanation to teaching practices that move from students' thinking to diagnosis, assessment-informed instruction, and adjustment to students' thinking. This study contributes to the literature on mathematics teacher education (MTE) by showing how attending to PCK as professional knowledge in action during mathematics lessons, rather than as professional knowledge in possession of mathematics teachers, highlights the transformation of mathematical knowledge into practice used for the education of future mathematics teachers. To develop MTEs' learner-centered approach, diagnostic ability and adaptability in teaching geometry, the teacher education programmes need to align mathematics lessons with the mathematics curriculum, incorporating PCK. The study was conducted in Colleges of Education in one region of Ghana, so its findings are not generalizable to other contexts. A related limitation is that it partially relies on PSTs' perceptions of MTEs' PCK and does not collect direct evidence of the pedagogical skill of the MTEs. The relatively small, qualitative MTE sample ($n = 12$) limited perspectives and experiences reported. Future research may involve larger samples of PSTs, multiple geographic locations, and/or classroom observations of MTEs to gather additional perspectives and enactments of geometry PCK within mathematics teacher education. In conclusion, MTEs need to consider not only what they know about mathematics but how they model the doing of helping others come to understand and teach mathematics for preparing future mathematics teachers. Mathematical knowledge and the pedagogical strategies of learning for learners can be improved for geometry instruction in teacher education programmes.

Contribution to Knowledge

This study makes a contribution to literature related to mathematics teacher preparation and education by providing new information about PSTs' perceptions and experiences of MTEs' PCK enactment when teaching

geometry in the Ghanaian context beyond what they explained. Even though several studies related to mathematics knowledge of teachers and PSTs' challenges when learning and teaching geometry exist, our study shows PSTs' evaluation of MTE knowledge enactments during teaching. This study contributed by reporting that MTE effectiveness can show a developmental sequence. Mathematics content knowledge well developed at the end of mathematics curriculum does not straightforwardly transfer into effective learner-centred learning enactments. The study represents an empirical understanding that geometric content knowledge is not sufficient for teaching geometry. Rather, it is understood through the lenses of enactment of misconception diagnosis, adaptive differentiation, assessment-informed decision making, and technology use. A context-specific framework could provide a basis for the improvement of MTE professional development and the preparation of future mathematics teachers.

Recommendations

Based on the findings, the study offers the following recommendations:

- (a) Colleges of Education should support MTEs' development of practice-based PCK regarding diagnosing learners' misconceptions, providing adaptive geometry instructions, and teaching using learners' assessment data. Examples of practice-based PCK development approaches are reflective teaching, peer observation, and collaborative lesson improvement.
- (b) Teacher education programmes should help PSTs integrate digital geometry tools, including dynamic geometry software, into their students' lessons to support their visualization, exploration, and understanding of geometric concepts.
- (c) MTEs should increase opportunities for learner-centered approaches such as problem-solving collaboration, inquiry-based approaches, questioning and manipulatives to model effective teaching practices in geometry education for PSTs to use when teaching in the schools.
- (d) The Ministry of Education (MoE), the National Teaching Council (NTC) and other bodies responsible for education policy should develop in-service professional development programs for MTEs on geometry-specific PCK, continual development and the quality of mathematics teacher preparation for Colleges of Education in Ghana.

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