



Analysing Mathematical and Pedagogical Content Knowledge among Pre-Service Mathematics Teachers: A Comparative Study across the Three Northern Geopolitical Zones of Nigeria

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Abstract

Teachers' content and pedagogical knowledge are crucial elements of an effective teaching and learning process. However, a disciplined analysis of these constructs is lacking within the context of pre-service mathematics teachers in Nigeria. This study aimed to address this gap by advancing a comparative analysis of content and pedagogical knowledge and investigating the relationship between these constructs among pre-service mathematics teachers across the three geopolitical zones in northern Nigeria. Using a cross-sectional survey research design involving 539 pre-service mathematics teachers across the zones, the data were collected using validated and reliable instruments (coefficients of .79 and .85). The data were analysed using descriptive and inferential statistics to address the research questions and test the hypotheses. The results show significant differences in content knowledge among pre-service mathematics teachers in North-Central ($M = 64.08$), North-West ($M = 54.73$), and North-East ($M = 39.76$) zones. Pedagogical content knowledge also varies, with North-West scoring highest ($M = 4.42$), followed by North-Central ($M = 4.33$), and North-East ($M = 4.06$). A moderate positive correlation ($r = .475$) exists between content and pedagogical knowledge, with a significant relationship ($F(1, 537) = 156.23, p < .05$). The discussion explores both the theoretical and practical implications of these findings.

Keywords: content knowledge; pedagogical content knowledge; pre-service mathematics teachers; mathematical knowledge for teaching; teacher education

1 Introduction

Mathematics, frequently referred to as the universal language of science, significantly influences our comprehension of the world. Grounded in abstract concepts and logic, mathematics is fundamental to problem-solving and innovation. It is more than a collection of formulas and equations: it develops logical reasoning, critical thinking, and the ability to apply theory to practical problems in fields such as the natural sciences, economics, and engineering (Faruq, 2023). Nonetheless, despite its importance, the teaching of mathematics often fails to convey its elegance and practical relevance. Traditional, teacher-centred approaches, which prioritise transmission over interactive, student-centred learning, frequently result in superficial comprehension and disengagement, thereby restricting students' involvement with the subject (Alam, 2023). Structural issues exacerbate these challenges in Nigeria. Inadequate teacher training, obsolete instructional resources, and overcrowded classrooms hinder the successful implementation of the mathematics curriculum (Aduwa, 2021). Furthermore, many prospective teachers lack the pedagogical proficiency required to meet varied learner needs, stimulate student engagement, and foster mathematical reasoning (Sintema et al., 2023). Addressing these challenges is essential for preparing teachers who can connect theoretical knowledge with classroom practice.

Pre-service teachers — students enrolled in teacher education programmes leading to professional certification — are crucial to shaping future educational outcomes. These personnel undergo intensive training to develop pedagogical content knowledge (PCK), a blend of subject-matter mastery and effective instructional practices (Moh'd et al., 2022). For pre-service mathematics teachers, proficiency in content knowledge is crucial, as it allows them to anticipate misconceptions, tailor lessons to varied student requirements, and cultivate problem-solving abilities (Rahman, 2023).

Ball et al. (2008) similarly emphasise that content knowledge encompasses an understanding of the concepts, procedures, and structures of a discipline and provides the foundation for instructional activity. Pedagogical Content Knowledge (PCK), developed by Shulman (1987), highlights the distinct interaction between content expertise and instructional strategies. PCK empowers educators to convey intricate concepts in ways that students can comprehend and interact with. Mathematics educators must comprehend students' cognitive processes, anticipate difficulties, and implement pedagogical techniques that render abstract concepts comprehensible (Ball et al., 2008). Star (2023) emphasises that proficient teaching requires not only subject mastery but also the capacity to customise instruction to accommodate varied learning requirements.

In Nigeria, teacher education programmes integrate microteaching and practicum experiences to equip pre-service teachers for classroom realities. Microteaching offers a regulated context in which pre-service educators refine their instructional methods, whereas the teaching practicum provides practical experience in authentic classroom environments. These elements are essential for equipping pre-service teachers with the competencies and confidence required to manage the complexities of teaching (Babalola et al., 2024). Despite these endeavours, research reveals that the transition from theoretical instruction to practical implementation frequently poses considerable difficulties, as pre-service teachers may perceive themselves as inadequately prepared for the demands of classroom interaction (Yin, 2019). The National Policy on Education (Federal Republic of Nigeria [FRN], 2014) highlights the significance of ongoing professional development for educators, stressing the necessity for innovative pedagogical methods. In many Nigerian schools, instruction is often tedious and detached from students' needs, underscoring the pressing need for more practical, experiential training in pre-service teacher education (Mata, 2024).

Assessment is crucial for evaluating the efficacy of teacher education programmes. Assessments of pre-service teachers' knowledge, abilities, and attitudes provide insight into their preparedness for the teaching profession and guide the creation of tailored interventions to address any deficiencies. Efficient assessment methodologies can strengthen teacher preparation by promoting reflective practice, facilitating data-informed decision-making, and supporting the continuous improvement of instructional techniques (Guevarra et al., 2024; Okonkwo et al., 2025). Ideally, pre-service mathematics teachers in Nigerian universities should have a robust foundation in mathematical content knowledge (CK), which supports the development of pedagogical content knowledge (PCK). Together, these competencies facilitate effective instructional delivery and the capacity to identify and address learners' difficulties. However, the current situation in Nigerian universities indicates substantial challenges in the relationship between content knowledge and pedagogical practice among pre-service mathematics teachers. Research shows that many pre-service teachers exhibit gaps in content knowledge, which negatively affects their confidence, instructional methods, and capacity to respond to students' learning challenges (Njiku, 2025; Theron & Jita, 2026). These CK and PCK gaps impede the development of a strong grasp of mathematical concepts and lead to less-than-ideal student learning outcomes.

The existing literature mostly examines CK and PCK separately, ignoring their link and combined influence on instructional practice, despite the well-established significance of subject knowledge in determining teaching success (Sarkar et al., 2024; Belayneh, 2025). Furthermore, the impact of CK deficits on important instructional activities has received limited attention (Hoth et al., 2022). This deficiency in integrated research creates a significant knowledge gap concerning the factors that undermine the efficacy and readiness of pre-service mathematics teachers (Edo et al., 2024). Addressing these gaps is essential for enhancing teacher education programmes and, consequently, the quality of mathematics education in Nigerian universities. This study addresses gaps in existing research (Otun & Olaoye, 2019; Barnes et al., 2019; Saidu, 2020; Ibrahim & Yew, 2023) by examining the relationship between mathematical content knowledge and pedagogical content knowledge among pre-service mathematics teachers in federal universities across northern Nigeria. The findings provide evidence-based insights for redesigning teacher education programmes so that pre-service teachers are adequately equipped to meet the demands of contemporary mathematics instruction. This research therefore aims to assess the extent to which pre-service mathematics teachers' content knowledge predicts their pedagogical content knowledge in federal universities in Northern Nigeria. To achieve this aim, the following research questions were raised and addressed:

1. What is the level of mathematical content knowledge possessed by pre-service mathematics teachers across the different geopolitical zones?
2. What is the level of pedagogical content knowledge possessed by pre-service mathematics teachers across the different geopolitical zones?
3. To what extent does pre-service mathematics teachers' content knowledge predict their pedagogical content knowledge?

The findings of this study carry specific implications for multiple stakeholders. For curriculum developers in Nigerian universities, the zonal disparities in CK and PCK highlight the need for differentiated teacher education programmes — particularly in the North-East, where both content and pedagogical knowledge lag behind. University administrators can use these results to allocate professional development resources and strengthen mathematics departments in underperforming zones. For pre-service teachers, the moderate CK–PCK correlation suggests that deepening subject-matter knowledge alone is insufficient; deliberate pedagogical training through microteaching and practicum must be intensified. Parents and school communities stand to benefit from better-prepared teachers who can represent mathematical concepts clearly and respond effectively to learners' difficulties. Finally, researchers in mathematics education can build on this comparative framework to investigate the institutional and contextual factors driving zonal differences, while policymakers at federal and state levels can use the evidence to inform equitable resource distribution across Nigeria's geopolitical zones.

2 Theoretical Perspectives

This study is grounded in two complementary theoretical frameworks: Shulman's (1987) pedagogical content knowledge (PCK) framework and Ball et al.'s (2008) mathematical knowledge for teaching (MKT) model. Shulman (1987) conceptualised PCK as the intersection of subject matter knowledge and pedagogical skill — the specialised knowledge that enables teachers to represent concepts accessibly, anticipate misconceptions, and adapt instruction to diverse learners. Ball et al. (2008) extended this reasoning into mathematics-specific territory, proposing MKT as a domain-specific construct comprising knowledge of content and students (KCS), knowledge of content and teaching (KCT), and knowledge of curriculum. Together, these frameworks provide the analytical lens for examining how pre-service teachers' content knowledge relates to their pedagogical competence.

Shulman's (1987) core hypothesis is that combining content knowledge (CK) with pedagogical knowledge (PK) results in a specialised form of knowledge known as pedagogical content knowledge (PCK). PCK involves the ability to represent and explain subject matter in ways that are accessible to students, including addressing misconceptions and tailoring instruction to meet the needs of diverse learners. This theory suggests that teaching effectiveness depends not only on knowing the subject but also on making that knowledge comprehensible to learners. In contrast, the MKT model posits that teaching mathematics requires specific knowledge beyond general pedagogy and content. MKT emphasises the integration of content knowledge, pedagogical knowledge, and an understanding of students' thinking: teachers must not only understand mathematics but also know how to teach it to students of varying abilities, recognising their thinking and adapting instruction accordingly. The hypothesis behind MKT is that high-quality teaching improves student outcomes because teachers are better equipped to address the challenges of mathematics instruction. While both frameworks have been critiqued for measurement challenges and insufficient attention to contextual factors, they remain the most widely accepted lenses for examining the knowledge demands of mathematics teaching. For this study, PCK and MKT jointly inform the investigation of how content knowledge predicts pedagogical competence across institutional and zonal contexts in northern Nigeria.

3 Methodology

3.1 Participants

The study adopted a cross-sectional survey research design and involved pre-service mathematics education students from federal universities across the nineteen states of the Northern Geographical Zones of Nigeria. The total population of mathematics education students in the 19 federal universities registered for the 2023/2024 academic year was 1,707. The study sample consisted of 539 final-year pre-service mathematics teachers selected from the 19 federal universities in the Northern Educational Zones through a multistage sampling procedure. In the first stage, a stratified random sampling approach was employed to choose one federal university from each of the nineteen states within the northern educational zones of Nigeria. In the second stage, a purposive sampling strategy was applied to select final-year pre-service mathematics teachers, who were considered most representative of the output of the teacher education programmes under study.

3.2 Measures

Data for the study were obtained using two instruments: the Mathematics Content Knowledge Performance Test (MCKPT) and the Pedagogical Content Knowledge Questionnaire (PCKQ).

3.2.1 Pedagogical Content Knowledge Questionnaire

The Pedagogical Content Knowledge Questionnaire (PCKQ) was developed from Bukova-Güzel et al. (2013) to assess participants' self-reported perceptions of pedagogical content knowledge. The tool comprises 10 items designed to measure participants' understanding and aptitude in teaching mathematical ideas effectively. Each item on the PCKQ was graded on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). All items were worded positively to ensure consistency in responses. The questionnaire focused on examining pre-service teachers' instructional tactics, representation of mathematical concepts, and their capacity to detect and address students' learning difficulties. To guarantee the validity of the research instrument, the PCKQ was examined by experts in mathematics education and psychometrics, and their feedback was incorporated to enhance clarity, relevance, and alignment with the study objectives. The reliability of the instrument was examined using Cronbach's Alpha. The PCKQ yielded a reliability coefficient of .85, indicating a high level of internal consistency.

3.2.2 Mathematics Content Knowledge Performance Test

The Mathematics Content Knowledge Performance Test (MCKPT) was developed to measure participants' content knowledge in secondary school mathematical subjects. The MCKPT was adapted from prior West African Senior School Certificate Examination (WASSCE) mathematics examination papers spanning the years 2005 to 2021. The test consisted of 20 multiple-choice questions, each scored as either correct (1 point) or incorrect (0 points). The total scores provided a measure of the participants' mathematical subject knowledge competency. The test covered core mathematical concepts, including algebra, calculus, geometry, and statistics. The researcher evaluated the data obtained from a pilot study to determine the reliability of the MCKPT using the test-retest approach, applying Pearson's Product-Moment Correlation Coefficient. The MCKPT yielded a reliability coefficient of .79, indicating acceptable test-retest consistency.

3.3 Data Collection Procedure

Data were collected between February and April 2024, during regular lecture periods in the participating universities. Prior to administration, the researchers obtained permission from the relevant university authorities and departmental heads. The MCKPT and PCKQ were administered face-to-face by the researchers and trained research assistants, who briefed participants on the purpose of the study and the procedures for completing the instruments. Participants completed both instruments in a single sitting lasting approximately 45 minutes. Of the 600 instruments distributed across the 19 universities, 539 were duly completed and returned, giving a response rate of 89.3%.

3.4 Data Analysis

The data were analysed using both descriptive and inferential statistics with the aid of SPSS version 23. Descriptive statistics, including means and standard deviations, were employed to answer the research questions. The following null hypotheses were formulated and tested at the .05 level of significance:

H_{01} : There is no significant difference in the level of mathematical content knowledge among pre-service mathematics teachers in federal universities across the three northern geopolitical zones.

H_{02} : There is no significant difference in the level of pedagogical content knowledge among pre-service mathematics teachers in federal universities across the three northern geopolitical zones.

H_{03} : Content knowledge does not significantly predict the pedagogical content knowledge of pre-service mathematics teachers.

One-way Analysis of Variance (ANOVA) was used to test H_{01} and H_{02} , that is, to determine whether there were significant variations in content knowledge and pedagogical content knowledge among pre-service mathematics teachers across the three northern geopolitical zones, and Scheffé post-hoc tests were conducted to locate the specific group

differences. Simple linear regression was used to test H_{03} and to estimate the extent to which content knowledge predicts pedagogical content knowledge.

3.5 Ethical Considerations

Ethical approval and an introductory letter were obtained from the Research Ethics Committee of the Department of Science Education, Ahmadu Bello University (ABU), Zaria. Permission was also obtained from the authorities of the participating universities. Participation was voluntary, and informed consent was obtained after the participants were adequately briefed on the purpose of the study. Participants were assured of the confidentiality and anonymity of their responses and their right to withdraw at any time without penalty. The completed instruments and research data were securely stored, accessed only by the researcher, and used solely for the study.

4 Results

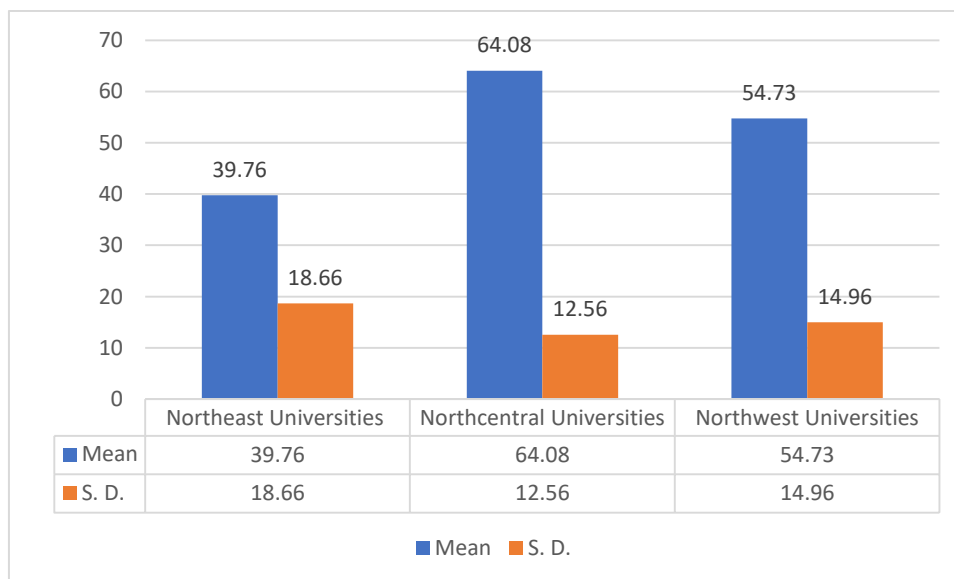
The three research questions were answered using descriptive statistics (means and standard deviations), while the null hypotheses were tested using ANOVA, Scheffé post-hoc analysis, and simple linear regression.

4.1 Research Question 1

The research question regarding the level of mathematical content knowledge possessed by pre-service mathematics teachers across the different geopolitical zones was answered using means and standard deviations. The results are presented in Figure 1 and Table 1.

Figure 1

Mean mathematics content knowledge scores by geopolitical zone.



As Figure 1 shows, pre-service teachers from North-Central universities had the highest level of content knowledge ($M = 64.08$, $SD = 12.56$), followed by those from North-Western universities ($M = 54.73$, $SD = 14.96$), while pre-service teachers from North-Eastern universities had the lowest level ($M = 39.76$, $SD = 18.66$). The larger standard deviation in the North-East indicates wider variation in content knowledge in that zone. To establish whether these differences were statistically significant, the data were subjected to one-way ANOVA. The results are summarised in Table 1.

Table 1

Summary of ANOVA for differences in the level of content knowledge among pre-service mathematics teachers across the zones

Source	Sum of Squares	df	Mean Square	F	p-value
Between Groups	41124.863	2	20562.431	97.716	< .001
Within Groups	112790.662	536	210.430		
Total	153915.525	538			

The ANOVA results in Table 1 indicate a significant difference in the level of mathematical content knowledge among pre-service mathematics teachers across the three geopolitical zones, $F(2, 536) = 97.716$, $p < .001$. The null hypothesis H_{01} was therefore rejected. To locate the specific differences, Scheffé's multiple comparison analysis was conducted, and the results are presented in Table 2.

Table 2

Scheffé multiple comparisons of content knowledge across zones

(I) Universities	(J) Universities	Mean Difference (I-Std. J)	Std. Error	p-value
North Eastern Universities	North Central Universities	-24.32*	1.77	< .001
	North Western Universities	-14.97*	1.89	< .001
North Central Universities	North Eastern Universities	24.32*	1.77	< .001
	North Western Universities	9.35*	1.40	< .001
North Western Universities	North Eastern Universities	14.97*	1.89	< .001
	North Central Universities	-9.35*	1.40	< .001

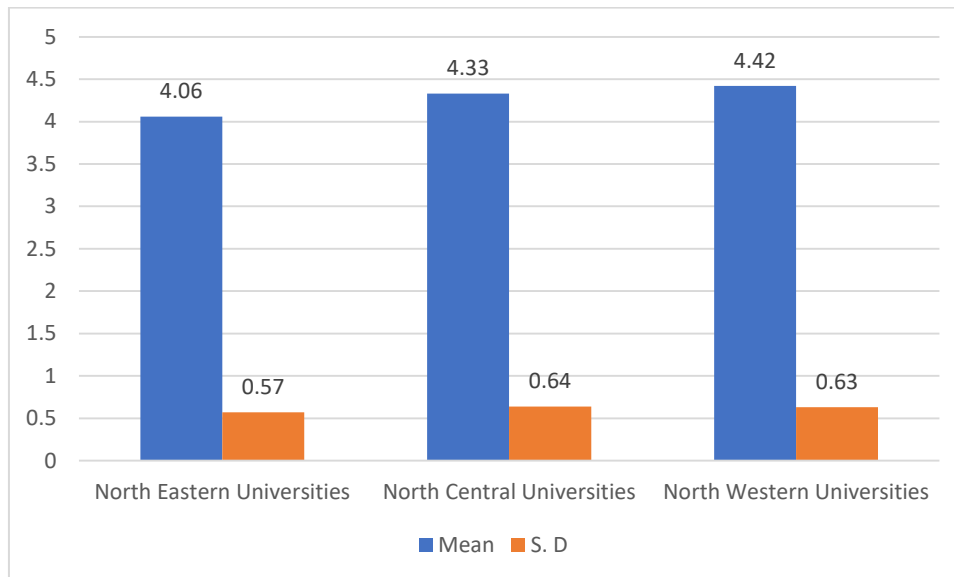
The Scheffé post-hoc results in Table 2 show that pre-service teachers in North-Central universities significantly outperformed their peers in both North-Eastern (mean difference = 24.32, $p < .001$) and North-Western universities (mean difference = 9.35, $p < .001$). Similarly, pre-service teachers in North-Western universities had significantly higher content knowledge than those in North-Eastern universities (mean difference = 14.97, $p < .001$). These results confirm that the content knowledge of pre-service mathematics teachers varies significantly across the geopolitical zones, with North-Central universities showing the highest proficiency.

4.2 Research Question 2

The second research question was answered using means and standard deviations to compare pedagogical content knowledge levels across the zones. The results are presented in Figure 2 and Table 3.

Figure 2

Mean pedagogical content knowledge scores by geopolitical zone



As Figure 2 shows, pre-service teachers from North-Western universities recorded the highest mean PCK score ($M = 4.42$), followed closely by those from North-Central universities ($M = 4.33$), while those from North-Eastern universities recorded the lowest mean score ($M = 4.06$). The standard deviations (ranging from 0.57 to 0.64) are relatively small, indicating low variability within each zone. To determine whether these differences were statistically significant, one-way ANOVA was applied, and the results are displayed in Table 3.

Table 3

Summary of ANOVA for differences in the level of pedagogical content knowledge among pre-service mathematics teachers across the zones

Source	Sum of Squares	df	Mean Square	F	p-value
Between Groups	7.839	2	3.920	10.113	< .001
Within Groups	207.735	536	.388		
Total	215.574	538			

The ANOVA results in Table 3 show a significant F-value, $F(2, 536) = 10.113$, $p < .001$, indicating that the differences in PCK across the three zones are statistically significant. The null hypothesis H_{02} was therefore rejected. A Scheffé post-hoc analysis was conducted to locate the differences, and the results are presented in Table 4.

Table 4

Scheffé multiple comparisons of pedagogical content knowledge across zones

(I) Universities	(J) Universities	Mean Difference (I-J)	Std. Error	p-value
North Eastern Universities	North Central Universities	-.27*	.08	.002
	North Western Universities	-.36*	.08	.000
North Central Universities	North Eastern Universities	.27*	.08	.002
	North Western Universities	-.09	.06	.344
North Western Universities	North Eastern Universities	.36*	.08	.000
	North Central Universities	.09	.06	.344

The Scheffé multiple comparisons in Table 4 show that pre-service teachers from North-Eastern universities possessed significantly lower pedagogical content knowledge than those from both North-Central (mean difference = $-.27$, $p = .002$) and North-Western universities (mean difference = $-.36$, $p < .001$). In contrast, there was no significant difference

between North-Central and North-Western universities (mean difference = $-.09$, $p = .344$). These results indicate that North-Eastern universities lag in pedagogical content knowledge, while the North-Central and North-Western zones are relatively similar in this regard.

4.3 Research Question 3

To address the third research question, the MCKPT and PCKQ scores were first analysed using Pearson's product-moment correlation to assess the strength and direction of the relationship between content knowledge and pedagogical content knowledge. The relationship is visualised in Figure 3.

Figure 3

Scatterplot of mathematics content knowledge and pedagogical content knowledge scores (N = 539) with fitted regression line.

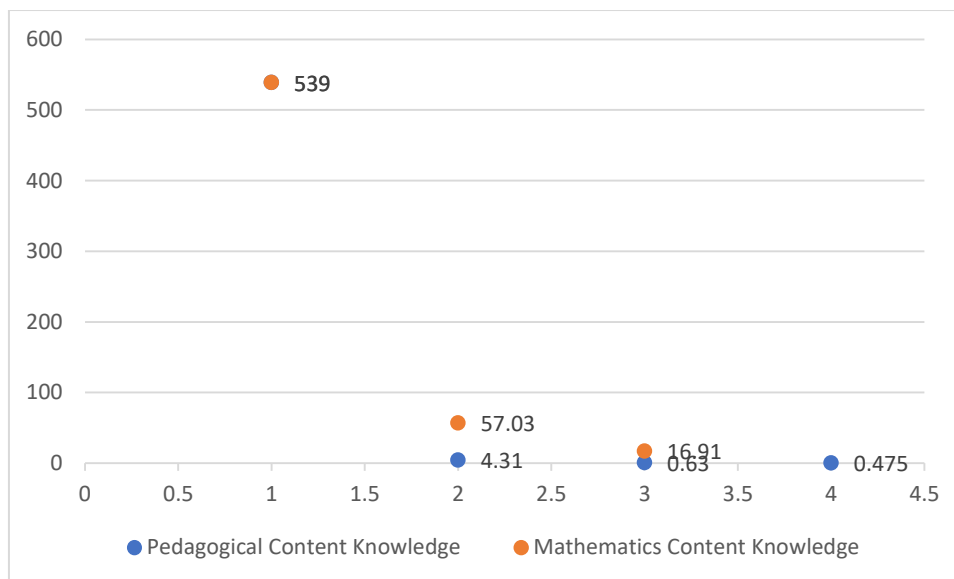


Figure 3 displays the paired CK and PCK scores of the 539 participants together with the fitted least-squares regression line. The upward slope of the line indicates that higher levels of mathematics content knowledge are generally associated with higher levels of pedagogical content knowledge. Although the points show some dispersion around the line, the overall positive pattern visually confirms the moderate positive relationship reported below. Descriptively, the mean PCK score was 4.31 (SD = 0.63), while the mean CK score was 57.03 (SD = 16.91).

The Pearson correlation coefficient was computed to assess the strength and direction of the relationship. A correlation of $r = .475$ was found, indicating a moderate positive correlation between content knowledge and pedagogical content knowledge: as pre-service teachers' content knowledge increases, their pedagogical content knowledge also tends to improve, albeit moderately. To estimate the extent to which pedagogical content knowledge is predicted by mathematics content knowledge, a simple linear regression was conducted. The results are presented in Table 5.

Table 5

Regression analysis predicting pedagogical content knowledge from content knowledge

Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t-value	p-value
(Constant)	3.299	.085		39.025	< .001
Mathematics Content Knowledge	.018	.001	.475	12.499	< .001

$R^2 = .226$. Dependent variable: Pedagogical Content Knowledge

Table 5 presents the unstandardised and standardised coefficients of the regression model. The unstandardised coefficient ($B = .018$) indicates that for each one-unit increase in mathematics content knowledge, pedagogical content knowledge increases by .018 units. The standardised coefficient ($Beta = .475$) confirms that content knowledge is a moderate predictor of pedagogical content knowledge and aligns with the correlation result. The coefficient of determination, $R^2 = .226$, indicates that approximately 22.6% of the variance in pedagogical content knowledge is explained by pre-service teachers' content knowledge, while the remaining variance is attributable to other factors. The model was statistically significant, $F(1, 537) = 156.23$, $p < .05$, leading to the rejection of $H03$. This implies that improvements in content knowledge are likely to be accompanied by better pedagogical content knowledge among pre-service mathematics teachers.

5 Discussion

This study investigated pre-service mathematics teachers' content knowledge (CK) and its relationship with pedagogical content knowledge (PCK) across federal universities in Northern Nigeria. The findings revealed moderate overall mathematics content knowledge with significant differences across the three geopolitical zones. Pre-service teachers from North-Central universities demonstrated the highest CK, followed by those from the North-West, while participants from the North-East recorded the lowest performance. These regional differences suggest variations in the quality of teacher preparation, instructional resources, curriculum implementation, and learning opportunities across institutions. The finding supports previous studies that reported institutional and contextual factors as important determinants of pre-service teachers' mathematical competence (Ekawati et al., 2022; Fitriani, 2023; Ibrahim & Yew, 2023; Belayneh, 2025). It also reinforces the proposition of Ball et al.'s (2008) Mathematical Knowledge for Teaching framework that strong subject matter knowledge forms the foundation of effective mathematics instruction.

The study further found significant differences in pedagogical content knowledge among the three geopolitical zones. Although pre-service teachers generally demonstrated relatively high PCK, those from North-Western universities recorded the highest mean score, while those from North-Eastern universities obtained the lowest. This finding indicates that teacher education programmes differ in their effectiveness in developing instructional competence, particularly in transforming mathematical knowledge into meaningful classroom practice. The result agrees with Wicaksono and Dwipa (2020), Greefath et al. (2021), Leong et al. (2021), Sintema et al. (2023), Sarkar et al. (2024), and Njiku (2025), who reported that institutional context, quality of teacher preparation, practicum experiences, and curriculum design significantly influence the development of pedagogical content knowledge among pre-service teachers. These findings further support Shulman's (1987) theory that effective teaching depends on integrating content knowledge with appropriate pedagogical strategies.

The study also established a statistically significant moderate positive relationship between mathematics content knowledge and pedagogical content knowledge. This finding indicates that improvements in mathematical understanding are associated with better instructional decision-making and a greater ability to present mathematical concepts effectively. The regression results further demonstrate that content knowledge significantly predicts pedagogical content knowledge, confirming that mastery of mathematics provides a foundation for effective teaching practice. This finding is consistent with Agathangelou and Charalambous (2020), Oztay and Boz (2022), Ibrahim and Yew (2023), Star (2023), Sarkar et al. (2024), and Belayneh (2025), who reported that strong disciplinary knowledge enhances teachers' instructional competence and supports effective classroom practice. Nevertheless, the moderate strength of the relationship — with roughly 77% of the variance in PCK attributable to other factors — suggests that content knowledge alone is insufficient for developing high-quality teaching. Other factors, including teaching practice, reflective experiences, mentoring, classroom exposure, and institutional support, also contribute substantially to pedagogical competence, as reported by Moh'd et al. (2022), Babalola et al. (2024), Guevarra et al. (2024), Okonkwo et al. (2025), and Njiku (2025).

In general, the findings provide empirical support for both Shulman's Pedagogical Content Knowledge framework and Ball et al.'s Mathematical Knowledge for Teaching model, which emphasise that effective mathematics teaching requires the integration of deep disciplinary knowledge with appropriate pedagogical skills. Consequently, mathematics teacher education programmes in Nigerian universities should strengthen both mathematical content mastery and pedagogical training through improved practicum experiences, continuous mentoring, and evidence-based instructional approaches to enhance the professional competence of future mathematics teachers.

6 Limitations of the Study

The findings should be interpreted in light of four limitations. First, the cross-sectional design permits assessment of associations and statistical prediction but does not establish causal relationships between CK and PCK. Second, PCK was measured through self-report, which may be affected by social desirability and overestimation; observed teaching performance might produce different results. Third, the study was limited to federal universities in the three northern geopolitical zones, thereby restricting the generalisability of the findings to state and private universities and institutions in southern Nigeria. Finally, although CK significantly predicted PCK, the R^2 value of .226 indicates that CK explained 22.6% of the variance in PCK, suggesting that other factors not examined in the study also contribute substantially to PCK.

7 Directions for Future Research

Future studies could adopt longitudinal designs to examine how the CK–PCK relationship develops as pre-service teachers progress through practicum and into early professional practice. Research could also broaden the sampling frame to include state and private universities across Nigeria’s six geopolitical zones to enable wider comparative analysis. Combining self-report PCK measures with classroom observations or performance-based assessments could further strengthen measurement validity. Given the comparatively lower CK and PCK observed among participants from the Northeast, qualitative or mixed-methods studies could investigate institutional factors, including staffing, instructional resources, supervision, and school–university partnerships, that may contribute to zonal differences in teacher preparation.

8 Conclusion

Based on the findings, the study concludes that pre-service mathematics teachers in North-Central universities demonstrated the highest level of content knowledge, followed by those in North-Western and North-Eastern universities, indicating significant regional differences. In contrast, pre-service teachers in North-Western universities exhibited the highest level of pedagogical content knowledge. The findings further revealed a moderate positive relationship between content knowledge and pedagogical content knowledge, suggesting that stronger mathematical content knowledge is associated with higher pedagogical content knowledge, although content knowledge alone may not be sufficient for effective mathematics teaching. Accordingly, teacher education programmes in Nigerian universities should strengthen both mathematical content knowledge and pedagogical preparation, with particular attention to identified regional needs, especially in the North-East.

9 Declarations

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest

Data Availability Statement: The dataset is available upon request from the corresponding author.

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