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Assessing Topic-Specific Pedagogical Content Knowledge in Mathematics Instruction: Evidence from C. K. Tedam University of Technology and Applied Sciences, Ghana

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Abstract

This study examined the topic-specific pedagogical content knowledge (PCK) of mathematics education teachers at C. K. Tedam University of Technology and Applied Sciences (CKTUTAS), Ghana. While generic aspects of PCK such as knowledge of students' understanding and instructional strategies are widely studied, topic-specific dimensions including curricular saliency and representations remain underexplored in Ghanaian teacher education. Using a descriptive survey design, data were collected from 98 undergraduate and postgraduate mathematics education students through a structured questionnaire adapted from established PCK frameworks. Descriptive statistics, correlation analysis, and chi-square tests were employed to analyze the extent to which participants demonstrated topic-specific pedagogical competence. Findings revealed that teachers exhibited moderate levels of curricular saliency and limited knowledge of multiple representations, suggesting challenges in connecting mathematical topics and adapting content for different learners. These results highlight the need for teacher education programs to embed structured opportunities that build topic-specific PCK alongside generic pedagogical skills. Policy recommendations include revising curricula to incorporate task-based learning and content-focused pedagogical training.

Keywords: topic-specific pedagogical content knowledge, mathematics education, curricular saliency, multiple representations, Ghana

Introduction

Pedagogical content knowledge (PCK) is widely regarded as a cornerstone of effective teaching, combining subject matter expertise with an understanding of how to make content accessible to learners (Shulman, 1986). While generic aspects of PCK, such as knowledge of student understanding and instructional strategies, have been emphasized in teacher education research (Hill, Ball, & Schilling, 2008), topic-specific PCK, which includes curricular saliency and knowledge of representations, is equally crucial for mathematics instruction. Curricular saliency involves teachers' ability to recognize the relative importance of mathematical ideas and to connect them across topics (Grossman, 1990), while knowledge of representations refers to the use of multiple methods and models to explain concepts to diverse learners (Mavhunga & Rollnick, 2013).

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Research has shown that weaknesses in topic-specific PCK can significantly undermine the quality of mathematics teaching, as teachers may struggle to make content coherent or accessible to students (Depaepe, Verschaffel, & Kelchtermans, 2013). International studies, such as TEDS-M, have highlighted variability in teachers' ability to connect curricular content across topics (Tatto et al., 2012), while African-based studies have noted that pre-service teachers often rely on procedural approaches without demonstrating conceptual connections (Ayebo & Assuah, 2017). In Ghana, persistent concerns about mathematics achievement among students (Anamuah-Mensah, 2020) call for closer examination of how teacher education programs foster topic-specific pedagogical skills.

Against this backdrop, this study investigated the topic-specific PCK of mathematics education teachers at CKTUTAS, with a focus on curricular saliency and knowledge of multiple representations. The goal was to assess the extent to which teachers demonstrate competence in these areas and to explore implications for teacher education and mathematics instruction in Ghana.

Methods

Research Design

A descriptive survey design was employed to examine topic-specific pedagogical content knowledge among mathematics education teachers. This design was appropriate for capturing variations in curricular saliency and representation knowledge across a relatively large sample of respondents (Creswell & Creswell, 2018).

Participants

The study involved 98 mathematics education students enrolled at C. K. Tedam University of Technology and Applied Sciences. The sample comprised 62 males (63.3%) and 36 females (36.7%), including both undergraduate (n = 54, 55.1%) and postgraduate students (n = 44, 44.9%). Participants ranged in age from 20 years to above 31 years, ensuring a diverse profile of teacher trainees.

Instrumentation

Data were collected using a structured questionnaire adapted from established PCK frameworks (Hill et al., 2008; Mavhunga & Rollnick, 2013). Items assessed teachers' ability to identify curricular priorities, connect mathematical topics, and use multiple representations to teach concepts. Responses were rated on a 5-point Likert scale ranging from strongly disagree to strongly agree. The instrument was validated by experts in mathematics education and piloted with a smaller group of students before full administration.

Data Collection Procedure

The questionnaires were administered in person after prior arrangements with course instructors. Participants were briefed on the objectives of the study and given sufficient time to respond. Completed questionnaires were retrieved on the same day to ensure a high response rate.

Data Analysis

The data were coded and analyzed using SPSS version 25. Descriptive statistics (means, frequencies, percentages) were used to

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summarize responses. Correlation analysis examined the relationships between curricular saliency and representation knowledge, while chi-square tests explored associations between demographic factors and topic-specific PCK. A significance threshold of $p < .05$ was adopted.

Ethical Considerations

Ethical clearance was obtained from the Faculty of Education at C. K. Tedam University of Technology and Applied Sciences. Participation was voluntary, and informed consent was obtained from all respondents. Participants were assured of confidentiality, anonymity, and the right to withdraw from the study at any stage without penalty. Data were stored securely and used strictly for academic purposes.

Results

Table 1

Demographic Distribution of Respondents (N = 98)

Variable	Category	Frequency (n)	Percentage (%)
Sex	Male	62	63.3
	Female	36	36.7
Age	20–25 years	42	42.9
	26–30 years	38	38.8
	31 years & above	18	18.3
Educational Level	Undergraduate	54	55.1
	Postgraduate	44	44.9

As shown in Table 1, males (63.3%) constituted a larger proportion of the sample than females (36.7%). The majority of participants were within the youthful age brackets of 20–25 years (42.9%) and 26–30 years (38.8%). Slightly more than half of the respondents were undergraduates (55.1%), while the remaining 44.9% were postgraduate students. This demographic distribution provided a balanced basis for examining topic-specific pedagogical content knowledge across gender, age, and educational levels.

Table 2

Descriptive Statistics of Topic-Specific PCK Components (N = 98)

Component	Mean	SD	Interpretation
Curricular Saliency	3.41	0.58	Moderate
Knowledge of Representations	3.28	0.62	Moderate-Low

Table 2 shows that respondents scored moderately on curricular saliency (M = 3.41, SD = 0.58), indicating that while some participants were able to identify key concepts and connect mathematical topics, others struggled to do so effectively. Knowledge of multiple representations scored slightly lower (M = 3.28, SD = 0.62), suggesting that many respondents had difficulties in using varied models and approaches to explain mathematical concepts. This highlights a weakness in translating content knowledge into diverse pedagogical strategies.

Table 3

Correlation between Curricular Saliency and Representation Knowledge (N = 98)

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Variables	r	p-value
Curricular Saliency × Representation Knowledge	.46	.001

The results in Table 3 reveal a moderate, statistically significant positive correlation between curricular saliency and knowledge of representations (r = .46, p = .001). This suggests that respondents who were better at recognizing the importance of key mathematical concepts and linking topics were also more likely to demonstrate stronger use of multiple representations.

Table 4

Chi-Square Tests of Association between Demographics and PCK Components (N = 98)

Variable	χ^2	df	p-value
Gender × Curricular Saliency	1.27	1	.26
Gender × Representations	0.98	1	.32
Age × Curricular Saliency	2.54	2	.28
Age × Representations	3.11	2	.21
Educational Level × Curricular Saliency	0.84	1	.36
Educational Level × Representations	1.05	1	.31

As shown in Table 4, there were no statistically significant associations between demographic variables (gender, age, educational level) and either curricular saliency or representation knowledge. This indicates that the challenges in developing topic-specific PCK were not limited to particular demographic groups but were shared across all categories of mathematics education teachers.

Summary of Findings

The results showed that mathematics education teachers at C. K. Tedam University of Technology and Applied Sciences demonstrated moderate competence in curricular saliency and relatively lower competence in the use of multiple representations. A significant positive correlation was found between these two components, suggesting they reinforce one another. However, demographic factors such as gender, age, and educational level did not significantly influence topic-specific PCK, indicating systemic challenges in teacher preparation programs.

Discussion

This study assessed the topic-specific pedagogical content knowledge (PCK) of mathematics education teachers at C. K. Tedam University of Technology and Applied Sciences in Ghana, focusing on curricular saliency and knowledge of multiple representations. The findings showed that participants demonstrated moderate competence in curricular saliency and slightly lower competence in the use of representations. A moderate positive correlation was observed between the two dimensions, while no significant associations were found between demographic factors and topic-specific PCK.

The moderate scores on curricular saliency indicate that while some teacher trainees were able to recognize the relative importance of

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mathematical concepts and make curricular connections, others struggled to establish coherence across topics. This aligns with international studies showing that teachers often face difficulties in prioritizing mathematical ideas and sequencing them appropriately for instruction (Hill, Ball, & Schilling, 2008; Tatto et al., 2012). In Ghana, this may be linked to the structure of teacher preparation programs, which have historically emphasized mastery of content over the integration of content with pedagogy (Anamuah-Mensah, 2020; Osei, 2006).

Knowledge of representations was found to be weaker compared to curricular saliency. This finding is consistent with prior studies suggesting that pre-service mathematics teachers often rely heavily on procedural explanations and are less adept at using varied models and representations to support conceptual understanding (Depaepe, Verschaffel, & Kelchtermans, 2013; Ayebo & Assuah, 2017). The limited use of multiple representations can hinder teachers' ability to address diverse learner needs, particularly in mathematics classrooms where abstract concepts often require concrete or visual reinforcement (Kind, 2009; Kleickmann et al., 2013).

The positive correlation between curricular saliency and knowledge of representations underscores the interconnectedness of topic-specific PCK components. Teachers who can identify the relative importance of concepts and connect them across topics are more likely to use varied representations effectively. Similar findings have been reported in science and mathematics education research, where strong curricular awareness has been shown to enhance teachers' ability to adapt and diversify their teaching strategies (Mavhunga & Rollnick, 2013; Park & Oliver, 2008).

Importantly, the lack of significant demographic effects suggests that challenges in topic-specific PCK are systemic rather than confined to gender, age, or educational level. This mirrors earlier findings in Article 3 of this series and is consistent with international evidence from TEDS-M, which concluded that structural aspects of teacher education programs have a stronger influence on teacher knowledge than demographic characteristics (Tatto et al., 2012; Blömeke & Delaney, 2012).

These findings have clear policy implications. First, teacher education curricula in Ghana should be revised to explicitly emphasize the development of topic-specific PCK. Modules on curricular saliency should help teacher trainees identify core mathematical concepts, anticipate student difficulties, and establish conceptual linkages across topics. Similarly, training in representation should encourage teachers to move beyond procedural teaching and adopt multiple instructional models such as visual, symbolic, and contextual approaches. Universities such as C. K. Tedam University of Technology and Applied Sciences could integrate task-based learning, micro-teaching, and lesson study approaches into their mathematics education programs (Clarke & Hollingsworth, 2002; Darling-Hammond, 2017). At the national level, the Ministry of Education and Ghana Education Service could develop continuous professional development programs focused on strengthening topic-specific PCK

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among both pre-service and in-service mathematics teachers.

This study, however, has limitations. The reliance on self-reported data may have introduced bias, as participants could have overestimated their pedagogical competence. In addition, the study was limited to a single institution, reducing the generalizability of the findings to the broader Ghanaian context. A cross-sectional design was used, which did not capture the developmental progression of PCK over time. Future research should employ longitudinal designs and incorporate observational and interview data to triangulate findings. Expanding the study to include multiple teacher education institutions in Ghana would also provide a more comprehensive understanding of the state of topic-specific PCK nationwide.

Conclusion

This study explored the topic-specific pedagogical content knowledge of mathematics education teachers at C. K. Tedam University of Technology and Applied Sciences in Ghana, focusing on curricular saliency and knowledge of multiple representations. The findings revealed that while teachers demonstrated moderate competence in curricular saliency, their ability to use multiple representations was relatively weaker. A significant positive correlation between the two dimensions suggested that curricular awareness supports teachers' ability to employ varied instructional models.

Demographic factors such as gender, age, and educational level did not significantly influence topic-specific PCK, highlighting that challenges in this area are systemic across trainee groups. This underscores the need for teacher education programs to prioritize structured opportunities for building curricular saliency and representation skills. For policy and practice, embedding task-based learning, lesson study, and practice-oriented pedagogical training within teacher education curricula would help address these gaps. At the national level, professional development initiatives should explicitly target topic-specific aspects of mathematics pedagogy to improve overall teacher effectiveness and learner outcomes.

Although this study provides valuable insights, it was limited by its reliance on self-reported data and its single-institution sample. Future studies should adopt mixed-methods designs across multiple institutions to provide a more comprehensive picture of topic-specific PCK in Ghana. Nevertheless, the findings point to an urgent need for reforms in teacher education programs to strengthen the integration of mathematical content with pedagogical strategies.

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