European Journal of Contemporary Education
E-ISSN 2305-6746
2024. 13(4): 615-624
DOI: 10.13187/ejced.2024.4.615
https://ejce.cherkasgu.press

The Problems of Contemporary Education

Teacher Knowledge in Early-Grade Mathematics: Comparing Early Career and Pre-Service Teachers in Ghana

Marlene Kafui Amusuglo [a, *]

[a] Faculty of Education, Charles University, Prague, Czech Republic

Abstract

This study focuses on the pedagogical content knowledge (PCK) of pre-service and in-service early-grade mathematics teachers, contributing to the ongoing discussion on PCK. The Mathematics Pedagogical Content Knowledge Instrument (MPCKI) was used to collect data from forty pre-service and in-service early-grade teachers in Ghana. The higher PCK scores observed among pre-service teachers suggest that current teacher education programmes in Ghana effectively provide a solid theoretical foundation. However, the challenges reported by early-career teachers indicate a need to bridge the gap between theory and practice. Therefore, teacher education programmes should incorporate more practical, classroom-based experiences to better prepare teachers for the realities of Ghanaian classrooms. The results indicate that pre-service early-grade teachers have a higher level of PCK for teaching mathematics and suggest that pre-service teachers may be better equipped to effectively communicate mathematical concepts and enhance learners' mathematical thinking than their early-career counterparts. The findings underscore the importance of robust teacher preparation programmes in developing pedagogical content knowledge which is crucial for effective mathematics instruction in the early grades.

Keywords: in-service early grade teachers, pre-service early grade teachers, pedagogical content knowledge, early career teachers.

1. Introduction

The task of assessing teachers' knowledge base has proven challenging due to various interpretations provided by researchers over the years (e.g., Ball, Bass, 2000 and Hill et al., 2008). According to King (2020), one of the most important issues in professional learning is how to investigate and gain insight into the connection between theory and practice, what is learned

* Corresponding author
E-mail addresses: mkamusuglo@outlook.com (M. Kafui Amusuglo)

during pre-service education and what is used in the classroom. Shulman (1986) introduced a model that outlines seven types of teacher knowledge: general pedagogical knowledge, knowledge of student characteristics, understanding of educational contexts, awareness of educational purposes and values, content knowledge, curriculum knowledge, and pedagogical content knowledge (PCK). In subsequent work, he concentrated on three key areas: subject matter knowledge (SMK), pedagogical content knowledge, and curriculum knowledge. Building on Shulman's ideas, Hill and Craig (2022) propose that teachers use five distinct knowledge domains: personal, contextual, pedagogic, sociological, and social. This broader framework acknowledges the increasing diversity in classrooms and the complex interactions between teachers and their knowledge (Darling-Hammond, 2006; Ball et al., 2008). These issues of pedagogical training, subject matter expertise, and practical experience are notably significant in Ghana, especially since they played a key role in the curriculum review (MoE, 2019).

2. Results

Conceptualisation of pedagogical content knowledge (PCK)

Shulman (1986) introduced the concept of Pedagogical Content Knowledge (PCK), focusing on the interplay between subject knowledge, school knowledge, and pedagogic knowledge. His work emphasised a "teacher-centred pedagogy," which prioritises what teachers need to know, rather than focusing on the learning process itself. Shulman proposed a model where professional knowledge emerges from the interaction of these components, placing "personal constructs" at the centre of this active interchange. However, Depaepe et al. (2013) extended Shulman's ideas by highlighting the ongoing evolution of PCK and its relevance to teaching practice. However, Herold (2019) critiqued Shulman's model, noting that it is largely cognitive and individualistic in nature. The author advocated for a more expansive view of teacher learning and development, one that is situated within communities and contexts, rather than solely within individual cognition. This expanded view acknowledges the importance of collective knowledge-building within educational environments. Building on Shulman's (1986) perspective, Ball and her colleagues studied teaching in primary schools to identify challenges that require specific mathematical resources. They investigated the nature of mathematical knowledge, with a focus on how it is developed and applied in teaching environments. This analysis resulted in a practice-based framework called Mathematical Knowledge for Teaching (MKT), which includes various components: common content knowledge (CCK), specialised content knowledge (SCK), knowledge of content and teaching (KCT), knowledge of content and students (KCS), knowledge of students and teaching (KST), and knowledge of curriculum and assessment (KCA) (Ball et al., 2008). Ball and Bass (2000) emphasised that MKT is a specialised form of professional mathematical knowledge distinct from that needed in other fields, such as engineering, physics, or accounting. Similarly, Scheiner et al. (2019) further refined the concept of PCK by focusing on a teacher's ability to not only reconstruct mathematical concepts but also interpret how students understand these concepts. This skill makes students' mathematical thinking visible and requires continuous adaptation throughout each lesson, highlighting the depth of knowledge necessary for effective teaching.

Montenegro (2020) expanded on the development of PCK, suggesting that it allows teacher educators and students to collaborate in building knowledge about teaching. This collaborative process helps pre-service teachers envision their future roles. The development of PCK involves several stages, where teachers plan, evaluate resources, represent key ideas through examples or analogies, select effective teaching strategies, and differentiate materials based on their learners' needs, context, and abilities (la Velle, Newman, 2021).

Finally, a particularly relevant model for preschool and elementary teachers is the Knowledge Quartet by Rowland et al. (2007). This model emphasises the distinctions between subject matter knowledge and teachers' pedagogical content knowledge. The Knowledge Quartet model integrates the concept of mathematical knowledge into teaching practice, encompassing four key dimensions: foundation, transformation, connection, and contingency. The foundation focuses on teachers' understanding of students' potential errors, misconceptions, and familiarity with mathematical terminology. Transformation refers to how educators adapt their knowledge into clear demonstrations, examples, and representations to ensure student comprehension. Connection involves identifying and using the relationships between various mathematical topics and organising examples or tasks sequentially during lessons. Contingency highlights the teacher's capacity to think quickly and adapt to unforeseen situations in the classroom (Rowland et al.,

2009: 135). This model aligns with broader discussions on mathematical pedagogy, emphasising the dynamic role of teacher knowledge in shaping effective mathematics instruction (Shulman, 1986; Ball et al., 2008). The aim of this study is to explore the development of mathematical knowledge and teaching skills in initial teacher education programmes at the early-grade level in Ghana. Although there have been efforts to improve mathematics instruction through curriculum changes and research (Aboagye, Yawson, 2020), little empirical evidence exists regarding how pre-service teachers are being equipped with the practical skills and pedagogical expertise required for effective early-grade mathematics teaching. The authors argue that, unlike high-performing education systems that emphasize substantial hands-on training in teacher preparation, Ghana's teacher education programs may prioritise theoretical knowledge over crucial classroom experience (Darling-Hammond, 2006; Aboagye, Yawson, 2020). Given that student performance in mathematics has consistently fallen short of proficiency benchmarks (Hagan et al., 2020), this study aims to fill the research gap regarding the readiness of early-grade teachers to provide quality mathematics instruction, as highlighted by Hagan et al. (2020). The research is guided by the following hypothesis: There is no significant difference in the pedagogical content knowledge of early-grade mathematics between early career and pre-service teachers.

Instrumentation

The primary research question that directed this study was, "What level of pedagogical content knowledge for teaching mathematics do early career teachers and pre-service early-grade teachers possess?". To address the research inquiry, data were gathered from achievement tests that measured the pedagogical content knowledge (PCK) of mathematics teachers. The test scores for each group of grade teachers were analysed. The items included in the Mathematics Pedagogical Content Knowledge Instrument (MPCKI) were created for a study by Martin in 2017. These selected items were closely aligned with the mathematics content being studied by the participants, all fourth-year pre-service teachers, and corresponded to the questions in the National Standardized Test for Basic Four (4) in Ghana. The aim of this subject was to equip pre-service teachers with the essential knowledge and skills required to teach critical areas of the mathematics curriculum, such as algebra, measurement, geometry, and probability and statistics at the primary school level (Hagan et al., 2020; Martin, 2017).

Selection of participants

The population for this study consists of all final-year pre-service teachers enrolled in early-grade programmes at ten selected Colleges of Education in Ghana, as well as early-grade teachers in the initial years of their teaching careers who are actively employed in four chosen municipal districts across two regions of Ghana. Final-year pre-service teachers were specifically selected because they had completed all the necessary mathematics content courses (MoE, 2019). There are seven Colleges of Education in the Central and Western regions of Ghana. Moreover, there are twenty-two districts in the Central region and seventeen districts in the Western region. This location was selected for its convenience. A stratified random sampling technique was used to categorise the schools according to the Ghana Education Service (GES) classification. Schools from each of these categories were then randomly selected for the study. In total, twenty mathematics teachers from forty schools across two regions, representing all eight circuits in the Ghana Education Service (GES) categories (A, B, C, and D), participated in the study. Categories A and D represented schools in urban areas, while Categories B and C represented schools in rural areas (MoE, 2019).

Questionnaires were distributed to all twenty pre-service early grade teachers and twenty early grade teachers in the early years of their teaching careers across the eight districts within the Cape Coast Metropolis of the Central Region and the Sekondi-Takoradi Metropolis of Ghana, followed by interviews. During these visits, the study's purpose, the questionnaires' objectives, and completion instructions were discussed with both the pre-service teachers and teachers in the early years of their careers. In every CoE and school visit, the pre-service early grade teachers and teachers in the early years of their teaching careers demonstrated a willingness to partake in the research following the thorough explanation of the participant information and the assurance of confidentiality regarding their responses. Despite the advantages of questionnaires, such as anonymity, time efficiency, and standardised questions, they also come with limitations as noted by Munn and Drever (1995). In this study, although participants were willing to participate, ensuring a high response rate for completed questionnaires was a significant concern. Given the teachers

who agreed to participate, it was essential to develop strategies to increase response rates and enhance confidence in the results. The questionnaires were administered during the instructional hours of the pre-service teachers. An hour was requested of their time. They were collected on the same day they were administered, and the interviews followed shortly. The teachers, in their early years of teaching, responded after school hours.

Data analysis and discussion

Table 1 shows the distribution of scores achieved by all grade teachers. This includes early career and pre-service teachers who participated in the study on their teacher-made achievement test. The test scores were classified into different categories. For this analysis, both groups of early career teachers and pre-service grade teachers will be referred to as grade teachers.

Table 1. Distribution of test scores and their respective frequencies and percentages

Class	Frequency	Percentage
1–5	6	15
6–10	9	22.5
11–15	20	50
16–20	5	12.5
Total	40	100

Source: Field survey (2024)

Table 1 presents the frequencies and percentages corresponding to each group (both early career teachers and pre-service early grade teachers) on the test scores. The scores of these grade teachers exhibited an average level of pedagogical content knowledge, ranging from 6 to 15 marks. Additionally, 12.5 % of the grade teachers' test results showed exceptional performance. Their test results ranged between 16 and 20 marks; these grade teachers demonstrated a notably high level of pedagogical content knowledge. In comparison, these teachers showed commendable performance compared to others scoring below 10.

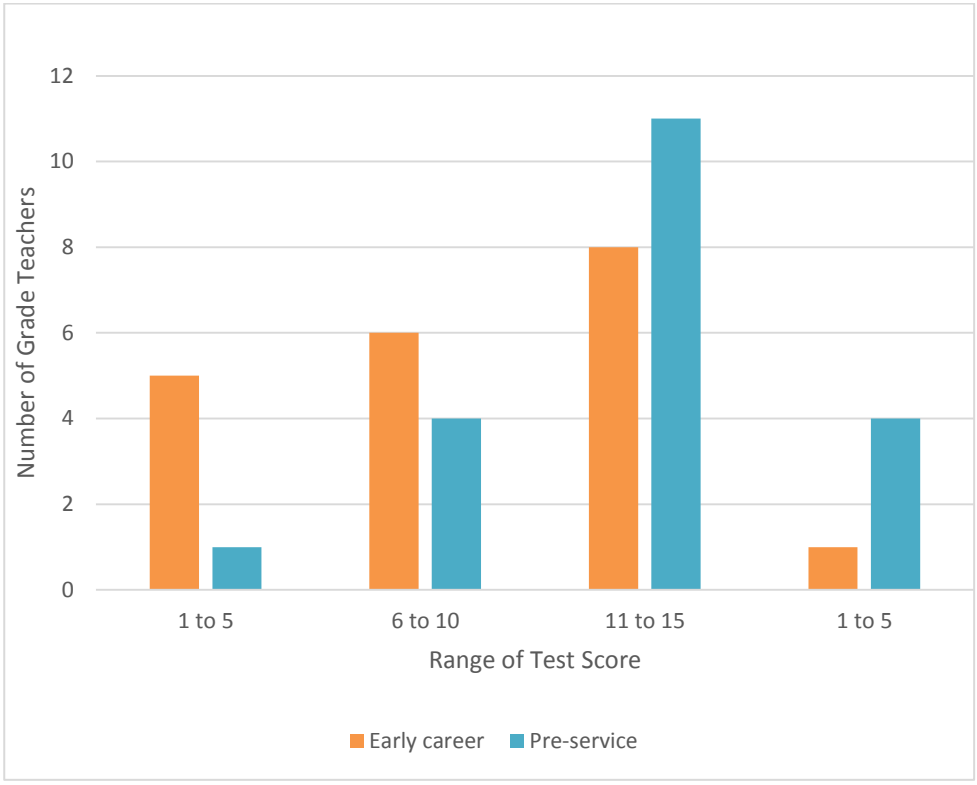

Fig. 1. Group test scores

Pre-Service Teachers: Most pre-service teachers scored within the highest range (11 to 15), indicating a stronger CK than their early career counterparts.

Early Career Teachers: The scores for early career teachers are more evenly distributed across the ranges, with a notable number scoring in the lowest (1 to 5) and highest (11 to 15) ranges.

This data suggests that pre-service teachers performed better on the PCK test than early career teachers, with a higher concentration of pre-service teachers scoring in the top range.

Research Hypothesis

The study was guided by the research hypothesis: There is no significant difference in the pedagogical content knowledge between early career and pre-service early grade teachers. In order to address this research hypothesis, the achievement test results of both early career and pre-service mathematics school teachers were used. The independent sample t-test was used to analyse the data collected from two groups of grade teachers in a teacher-made achievement test on pedagogical content knowledge for teaching mathematics. The analysis was conducted using a significant level of 5 %. Table 2 presents the descriptive statistics for the test scores of the two groups of early-grade mathematics teachers.

Table 2. Descriptive statistics of test scores of grade teachers

	N	Range	Min	Max	Mean	Std Deviation	Std. Error Mean
Early Career teachers	20	13	3	16	9.20	4.20	.94
Pre-service	20	13	5	18	12.10	3.58	.80

Source: Field survey (2024)

The data shown in Table 2 indicates that among the 40 early grade teachers who took part in the study, there were 20 early career grade teachers and 20 pre-service early grade teachers. The table indicates that both groups of early grade mathematics teachers possess an average level of pedagogical content knowledge (PCK) for teaching at the grade level.

The mean score of early career teachers was 9.20, with a standard deviation of 4.20. Meanwhile, the mean score of pre-service early grade teachers was also 12.10, with a standard deviation of 3.58. The scores of early career grade teachers varied between 3 and 16, whereas the results of pre-service early grade teachers ranged from 5 to 18. The aforementioned data about the range of test scores reveals that there is a difference in pedagogical content knowledge (PCK) between the two groups. However, pre-service early grade teachers possess a relatively higher level of PCK knowledge compared to early career grade teachers. The independent samples t-test can help determine if the difference in mean scores between early career and pre-service early grade teachers is statistically significant. The summary statistics are shown in Table 3.

Table 3. Results of Independent Samples t-test on test scores of Early career and Pre-service early grade teachers

	Levene's Test for Equality of Variances		t-test for Equality of Mean		
	F	Sig	T	Df	Sig (2 tailed)
Equal variances assumed	2.32	1.36	-2.35	38	.024

Source: Field survey (2024)

The test was conducted to assess if there is a significant difference in their PCK knowledge. The findings indicate a statistically significant difference in pedagogical content knowledge between the two groups of grade teachers. Using the Shapiro-Wilk normality test a sig value of .18 was obtained, which is greater than $\alpha = 0.05$. This implies that the data set is a normal distribution.

The mean score for early career grade teachers was 9.20, with a standard deviation of 4.20. On the other hand, pre-service early grade teachers had a mean score of 12.10, with a standard deviation of 3.58. The p-value was .024, which is less than the significance level α of 0.05. Therefore, we reject the null hypothesis and conclude that there is a statistically significant difference in the pedagogical content knowledge of early career grade teachers and pre-service early grade teachers. The statistically significant difference favours pre-service early-grade teachers. The observed difference in mean scores of the two groups of teachers is statistically significant. This indicates that pre-service early-grade teachers have a higher level of pedagogical content knowledge for teaching mathematics compared to early-career grade teachers. The findings indicate that pre-service early-grade teachers are more effective at teaching mathematics to students compared to early-career grade teachers. Additionally, this suggests that pre-service early-grade teachers can positively influence the mathematical thinking of primary school learners (Hagan et al., 2020; Martin, 2017).

Qualitative Phase

After collecting and analysing the quantitative data, ten early-career teachers who participated in the quantitative study were randomly selected, later contacted, and interviewed. Five themes emerged from this study. These themes include initial PCK development, factors influencing PCK development, challenges in PCK development, strategies for PCK improvement, and support systems and resources.

Table 4. Theme, sub themes and description of qualitative data of Early career and Pre-service early grade teachers.

Themes	Sub-themes	Description
Limited Initial PCK	Initial PCK development	Early-career teachers often start with traditional methods focused on procedural knowledge, limiting students' engagement with mathematical concepts.
Initial PCK Development	Growth and adaptation	With experience, teachers adapt their methods, balancing procedural knowledge with conceptual understanding.
Factors Influencing PCK Development	Classroom experience	Practical classroom experience is key to developing PCK as it provides opportunities to test theories and refine strategies.
	Professional development	Formal professional development helps teachers learn new strategies and improve their teaching methods.
	Collaboration with colleagues	Collaboration with more experienced colleagues fosters peer learning and contributes to PCK development.
	Resource constraints	Limited access to teaching resources restricts teachers' ability to implement diverse and innovative strategies.
	Time pressures	Teachers face time constraints due to the need to cover extensive curricula, leaving little room for reflection and improvement.
	Large class sizes	Large class sizes make implementing individualised attention and varied teaching methods difficult.

Themes	Sub-themes	Description
Strategies for PCK Improvement	Learner-centred approaches	Teachers shift to learner-centred methods to engage students in discussion and critical thinking.
	Real-world applications	Connecting mathematical concepts to real-world applications helps students see the relevance of mathematics.
	Collaborative learning	Teachers encourage student collaboration to enhance problem-solving and communication skills.
	Professional Development Opportunities	Professional development sessions provide ongoing learning opportunities for teachers to stay updated with new methodologies.
Support Systems and Resources	Peer Support	Teachers rely on peer support and department meetings to share best practices and troubleshoot challenges.
	Need for Additional Resources	Teachers express the need for more resources, including technology, to enhance student engagement and teaching effectiveness.

3. Discussion

The study on pedagogical content knowledge (PCK) for teaching mathematics among early career and pre-service early grade teachers reveals several findings that align with and extend previous research in this area. The mixed-method approach, combining quantitative analysis with qualitative interviews, provides a comprehensive view of the development and challenges of PCK in early mathematics education.

The quantitative phase of the study revealed that both early career and pre-service early-grade teachers possess an average level of pedagogical content knowledge (PCK) for teaching mathematics. However, a significant difference was found between the two groups, with pre-service teachers demonstrating a higher level of PCK. This finding is intriguing, as it somewhat contradicts the common assumption that classroom experience necessarily leads to higher PCK. This aligns with the work of Copur and Orrill (2023), who investigated the relationship between teaching experience and PCK among mathematics teachers. Their study highlighted that pre-service teacher, typically immersed in the most current research-based teaching methods and pedagogical training, often demonstrate stronger PCK than their early-career counterparts.

The findings suggest that while experience provides valuable classroom management skills and situational awareness, it does not always translate into higher PCK, especially when teachers are not engaging in continuous professional development focused on pedagogical skills. The qualitative phase of the study involved interviews with early career teachers, revealing five main themes: initial PCK development, factors influencing its growth, challenges in its development, strategies for improvement, and the role of support systems and resources.

The findings reveal that many early career teachers began with a traditional, procedural approach to mathematics teaching, focusing primarily on delivering subject matter knowledge through lectures, textbooks, and standard problem-solving exercises. This aligns with existing research that suggests early-career teachers often start with a limited view of pedagogical content knowledge (PCK), largely focused on the transmission of knowledge rather than fostering a deeper understanding of mathematical concepts. However, as teachers gained more experience, they began to shift towards more conceptual teaching practices. This highlights the importance of providing early-career teachers with opportunities to reflect on their teaching methods and make the transition from procedural to conceptual approaches, which are crucial for fostering deeper student understanding (Montenegro, 2020).

Classroom experience emerged as a critical factor in PCK growth, with participants emphasising that no amount of theoretical training could fully prepare them for the realities of the classroom. The experience of teaching, along with reflective practice, allowed teachers to adapt

their methods and incorporate more conceptual teaching strategies. This finding aligns with Montenegro's (2020) assertion that collaboration and hands-on experience play an essential role in building teaching knowledge. Teachers' exposure to real-world teaching scenarios facilitated their growth in understanding how to balance subject matter knowledge with pedagogical demands (Scheiner et al., 2019).

Resource limitations, time constraints, and large class sizes were consistently highlighted as significant challenges. These constraints often limited teachers' ability to implement learner-centred and conceptually rich teaching approaches. For example, the lack of sufficient teaching and learning materials, such as textbooks and technology, directly impacted teachers' ability to deliver high-quality instruction. The challenge of managing large class sizes further constrained efforts to adopt individualised and student-centred teaching methods, aligning with previous studies on the difficulties of teaching in resource-limited settings (Suters et al., 2021). These challenges highlight the need for systemic interventions to support teachers in overcoming these barriers.

Despite the challenges, teachers demonstrated a commitment to improving their PCK by adopting more learner-centred strategies and incorporating real-world applications into their lessons. This shift reflects a growing awareness of the importance of fostering conceptual understanding in students. For instance, one participant noted that integrating real-world applications into their lessons helped bridge the gap between abstract mathematical concepts and practical understanding. These strategies align with the literature on effective mathematics teaching, which advocates for a multi-dimensional approach that includes conceptual understanding, procedural fluency, and application (Dickerson et al., 2021). By actively seeking to improve their teaching methods, teachers showed adaptability and an openness to evolving their pedagogical practices.

Teachers identified the need for more resources, particularly in terms of technology and teaching materials. This reflects ongoing challenges in many educational contexts where resource limitations are common. The potential for technology to enhance mathematics instruction has been well-documented in the literature (Naufel et al., 2021), and teachers in this study expressed a desire for greater access to these tools to support their PCK development. Additionally, professional development opportunities, peer support, and focused feedback were mentioned as essential for continuous growth. This aligns with research by Donnelly and Berry (2019), who argue that ongoing professional development is key to supporting teachers in refining their PCK and addressing the challenges they face in the classroom.

4. Conclusion

The findings of this study provide valuable insights into the development of PCK among early career teachers. The qualitative phase reveals a complex and evolving process where teachers move from traditional, procedural teaching methods to more conceptual and learner-centred approaches. Classroom experience, reflective practice, and access to professional support systems were identified as key factors in this growth. However, challenges such as resource limitations and large class sizes continue to hinder teachers' ability to fully implement these approaches. The need for systemic support, particularly in providing adequate resources and professional development, is crucial for helping teachers develop the robust PCK needed for high-quality mathematics instruction.

Limitation of the study

One key limitation of this study was the relatively small sample size. The research was conducted in only two of the 170 districts in the country, with participants drawn from just four out of 102 basic schools in the two regions. While the sampling technique helped to maximise variation within the study sample, including additional districts would have allowed for a larger participant pool, providing a more representative view and enabling broader generalisation to a larger population. Despite this limitation, several findings from this study align with those of other researchers in the field of mathematics education (e.g., Suters et al., 2021).

Implication of the findings

The findings of this study hold substantial implications for improving the knowledge and skills necessary for initial mathematics teacher education and the early teaching experiences in Ghanaian Basic Schools.

Firstly, the higher PCK scores among pre-service teachers suggest that current teacher education programmes in Ghana are effective in providing a strong theoretical foundation. However, the challenges reported by early career teachers indicate a need to bridge the gap

between theory and practice. Teacher education programmes should incorporate more practical, classroom-based experiences to prepare teachers for the realities of Ghanaian classrooms.

Secondly, the identified challenges, particularly resource constraints and large class sizes, highlight the need for systemic support in Ghanaian education. Policy makers should prioritise providing adequate resources and addressing infrastructure issues to enable teachers to implement effective teaching strategies.

Thirdly, the importance of ongoing professional development and peer support suggests a need for structured mentoring programmes and regular in-service training opportunities in Ghanaian schools. These should focus on enhancing PCK, particularly in areas such as learner-centred approaches and integrating real-world applications in mathematics teaching.

Lastly, the expressed need for technological resources indicates an area for potential investment to support teachers' PCK development and enhance mathematics instruction in Ghanaian Basic Schools.

This study contributes to our understanding of PCK development in early career and pre-service early grade mathematics teachers. It highlights the interplay between theoretical knowledge, practical experience, and contextual factors in shaping teachers' PCK. The findings suggest that while pre-service education can provide a strong foundation in PCK, ongoing support, resources, and professional development opportunities are crucial for early career teachers to effectively apply and develop their PCK in classroom settings. This approach should cater to both the needs of individual teachers and the challenges within the system. Future research could explore the long-term trajectories of PCK development, the effectiveness of specific interventions in enhancing PCK, and strategies for overcoming resource constraints in challenging educational contexts.

References

Aboagye, Yawson, 2020 – *Aboagye, E., Yawson, J.A.* (2020). Teachers' perception of the new educational curriculum in Ghana. *African Educational Research Journal. 8*(1): 6-12.

Ball, Bass, 2000 – *Ball, D.L., Bass, H.* (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), Multiple perspectives on the teaching and learning of mathematics. Pp. 83-104.

Ball et al., 2008 – *Ball, D.L., Thames, M.H., Phelps, G.* (2008). Content knowledge for teaching: *What makes it special? Journal of Teacher Education*. 59(5): 389-407.

Copur-Gencturk, Orrill, 2023 – *Copur-Gencturk, Y., Orrill, C.H.* (2023). A promising approach to scaling up professional development: intelligent, interactive, virtual professional development with just-in-time feedback. *Journal of Mathematics Teacher Education,* 1-25.

Darling-Hammond, 2006 – *Darling-Hammond, L.* (2006). Powerful teacher education: Lessons from exemplary programmes. Jossey-Bass.

Depaepe et al., 2013 – *Depaepe, F., Verschaffel, L., Kelchtermans, G.* (2013). Pedagogical content knowledge: a systematic review of the way in which the concept has pervaded mathematicseducational research. *Teaching and teacher education.* 34: 12-25.

Dickerson et al., 2022 – *Dickerson, C., Levy R., Jarvis J., Thomas K.R.* (2022). Using a teacher knowledge framework to connect teaching practice with theory, *Journal of education for teaching*. 47 (4)3: 191-211.

Donnelly, Berry, 2019 – *Donnelly, J., Berry, L.* (2019). Considering the environment: an expanded framework for teacher knowledge. *Journal of learning spaces*. 8(1): 42-49.

Hagan et al., 2020 – *Hagan, J.E., Amoaddai, S., Lawer, V.T., Atteh, E.* (2020). Students' perception towards mathematics and its effects on academic performance. *Asian Journal of Education and Social Studies*. 8(1): 8-14.

Herold, 2019 – *Herold, F.* (2019). Shulman, or Shulman and Shulman? How communities and contexts affect the development of pre-service teachers' subject knowledge. *Teacher development*. 23(4): 488-505.

Hill, Craig, 2022 – *Hill, H.C., Craig, J.* (2022). Teacher learning: Building on new knowledge domains. *Educational Researcher*. 51(2): 102-110.

Hill et al., 2008 – *Hill, H., Ball, D., Schilling, S.* (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*. 39(4): 372-400.

Hill-Jackson, Craig, 2022 – *Hill-Jackson, V., Craig, C.J.* (2022). (Re)Constructing Teacher Knowledge: Old Quests for New Reform. *Journal of Teacher Education*. 74(1): 5-9.

King, 2020 – *King, F.* (2020). In conversation with practice. *Contemporary issues in practitioner education*. 2(2): 105-117.

la Velle, Newman, 2021 – *la Velle, L., Newman, S.* (2021). Becoming a teacher: What do teachers do? In S. Capel, M. Leask, S. Younie, E. H idson, & J. Lawrence (Eds.), Learning to teach in the secondary school: A companion to school experience (9th ed., pp. 37-51). Routledge.

Martin, 2017 – *Martin, A.* (2017). Development of a Mathematics Pedagogical Content Knowledge Instrument. *International Journal of Mathematics Education*. 15(3): 123-136.

Martin, Jamieson-Proctor, 2019 – *Martin, D., Jamieson-Proctor, R.* (2019). Development and validation of a survey instrument for measuring pre-service teachers' pedagogical content knowledge. *International Journal of Research Methods in Education*. 43(5): 512-525.

Ministry of Education, 2019 – Ministry of Education. National teacher education curriculum framework: The essential elements of initial teacher education, Accra, 2019.

Montenegro, 2020 – *Montenegro, H.* (2020). Teacher Educators' Conceptions of Modeling: A Phenomenographic Study. *Teaching and Teacher Education*. 94.

Munn, Drever, 1995 – *Munn, P., Drever, E.* (1995). Using Questionnaires in Small-Scale Research: A teacher's Guide Edinburgh, The Scottish Council for Research in Education.

Naufal et al., 2021 – *Naufal, M.A., Abdullah, A.H., Osman, S., Abu, M.S., Ihsan, H., Rondiyah, R.* (2021). Reviewing the Van Hiele model and the application of metacognition on geometric thinking. *International Journal of Evaluation and Research in Education*. 10(2): 597-605.

Rowland, Turner, 2007 – *Rowland, T., Turner, F.* (2007). Developing and using the 'Knowledge Quartet': A framework for the observation of mathematics teaching. *The Mathematics Educator*. 10(1): 107-123.

Rowland et al., 2009 – *Rowland, T., Turner, F., Thwaites, A., Huckstep, P.* (2009). Developing primary mathematics teaching: Reflecting on the floor. Sage Publications.

Scheiner et al., 2019 – *Scheiner, T., Montes, M.A., Godino, J.D., Carrillo, J., Pino-Fan, L.R.* (2019). What Makes Mathematics Teacher Knowledge Specialized? Offering Alternative *Views*. *International Journal of Science and Mathematics Education*. 17(1): 153-172.

Shulman, 1986 – *Shulman, L.S.* (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*. 15(1): 4-14.

Suters et al., 2021 – *Suters, L., Suters, H., Anderson, A.* (2021). STEM literacy in the classroom to enable societal change. *Contemporary Issues in Technology and Teacher Education*. 21(2): 491-526.

UNESCO, 2020 – UNESCO. Education: From disruption to recovery. 2020. [Electronic resource]. URL: https://en.unesco.org/covid-19/educationresponse