Moderating Effect of Mathematics Teaching Efficacy on the Relationship between Pedagogical Content Knowledge and Mathematics Teaching Anxiety

Bright Asare

Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana (ORCID: 0000-0001-8855-7687)

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Abstract: This study investigates the moderating effect of mathematics teaching efficacy in the relationship between pedagogical content knowledge and mathematics teaching anxiety. A survey research design was adopted, with a quantitative research approach. The study convenience sampling technique to select 249 in-service mathematics teachers from senior high schools in Kumasi, Ghana. To estimate the path coefficients, a structural equation modeling, and a Bias-Corrected percentile bootstrapping method were run in Amos (v.23). The study found that pedagogical content knowledge had a positive significant effect on mathematics teaching anxiety. Moreover, mathematics teaching efficacy had a positive effect on mathematics teaching anxiety. Finally, mathematics teachers' efficacy had a significant positive moderating effect on the relationship between pedagogical content knowledge and mathematics teaching anxiety. These findings underscore the importance of fostering mathematics teaching efficacy among mathematics teachers.

Keywords: Pedagogical content knowledge, Mathematics teaching anxiety, Mathematics teaching efficacy

1. Introduction

Mathematics education is increasingly recognized as a cornerstone for technological advancement and innovation in a rapidly evolving global society. The effectiveness of teaching mathematics hinges not only on a teacher's mathematical knowledge but also on their pedagogical content knowledge (PCK), which integrates an understanding of how to teach specific mathematical concepts in ways that are comprehensible to students. However, the influence of PCK on mathematics teaching anxiety (MTA), a pervasive issue among educators remains an area warranting further exploration. Mathematics teaching efficacy (MTE) plays a critical role as a mitigating factor, influencing how teachers perceive their ability to manage and deliver effective mathematics instruction despite experiencing anxiety.

Mathematics teaching efficacy refers to the confidence educators have in their ability to teach mathematics effectively and influence student learning outcomes (Yesilyurt et al., 2021). This concept, deeply rooted in Bandura's self-efficacy theory, is crucial because it impacts teaching practices and student engagement. Teaching efficacy is critical as it shapes the teacher's approach to instructional strategies, classroom management, and student engagement (Fackler et al., 2021). Teachers with high efficacy often adopt student-centered strategies, leading to better learning outcomes, while low efficacy can result in less effective teaching approaches.

Pedagogical Content Knowledge (PCK), as conceptualized by Romylos (2018), underscores the specialized knowledge teachers require to transform content into teachable material. Studies conducted in the United States have emphasized the importance of PCK in fostering student engagement and understanding. For instance, Ramaligela et al. (2019) highlighted that mathematics educators with strong PCK are better equipped to anticipate student misconceptions and adjust their teaching strategies accordingly. Similarly, Rowland and Turner (2007) developed the Knowledge Quartet framework, which underscores the interrelationship between PCK and classroom practices, reinforcing the argument that PCK directly impacts instructional quality. Mathematics teaching anxiety (MTA) refers to the feelings of tension and fear that educators experience when teaching mathematics (Patkin & Greenstein, 2020). This phenomenon is not confined to one region but is observed globally. A study by Bereczki and Kárpáti (2021) demonstrated that MTA negatively affects instructional creativity, limiting teachers' ability to adopt innovative methods. Similarly, Agyapong et al. (2022) revealed a strong correlation between MTA and teacher burnout, suggesting that sustained anxiety undermines educators' professional confidence and resilience. Furthermore, teachers with higher anxiety levels may exhibit avoidance behaviors in teaching specific mathematical concepts or rely on less interactive and engaging methods of instruction. This is supported by findings from Rozgonjuk et al. (2020), who noted a direct link between mathematics teaching anxiety and the reduced use of active teaching methods in the classroom, ultimately limiting students' opportunities for deep learning.

Teaching mathematics effectively requires educators to possess strong pedagogical content knowledge (PCK) and a high sense of teaching efficacy (Sintema & Marbán, 2020). PCK, which integrates the understanding of mathematical content and effective instructional strategies, enables teachers to communicate concepts clearly to

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students (Suh & Park, 2017). However, many mathematics teachers struggle to overcome teaching anxiety, a psychological barrier that hampers classroom performance and student engagement (Dwivedi, 2023). Research indicates that mathematics teaching efficacy (MTE), termed teachers' belief in their ability to teach mathematics successfully, may act as a buffer against the negative effects of teaching anxiety (Swackhamer et al., 2019). Despite the growing recognition of these interconnected factors, the relationship between PCK and teaching anxiety, and how MTE moderates this relationship, remains underexplored. Addressing this gap is crucial as mathematics teaching anxiety adversely affects instructional quality and, ultimately, student achievement (Zhang & Wang, 2020).

Mathematics teaching anxiety among educators is well documented, with studies revealing its significant impact on teachers' ability to convey mathematical concepts (Olson & Stoehr, 2019). Anxiety often stems from insufficient PCK, leading to low confidence and avoidance of innovative teaching methods (Rollnick, 2017). Additionally, teachers with poor PCK are more likely to rely on traditional, less effective instructional approaches, further perpetuating anxiety (Malenfant, 2021). Although existing research has explored the individual roles of PCK, teaching anxiety, and teaching efficacy, few studies examine how MTE moderates the relationship between PCK and teaching anxiety. Understanding this interaction is essential to provide a corresponding framework for improving teaching practices and reducing anxiety among mathematics teachers.

This study aims to fill the critical gap in the literature by investigating the moderating effect of MTE in the relationship between PCK and mathematics teaching anxiety. Prior research has emphasized the need for interventions targeting teacher efficacy to mitigate anxiety (Eugenia et al., 2024), yet limited attention has been given to how such interventions can enhance PCK's effectiveness in reducing anxiety. Addressing this issue has significant implications for teacher training programs, as enhancing MTE could improve teachers' ability to manage anxiety while leveraging their PCK. This research will provide empirical evidence for the design of targeted professional development initiatives to strengthen mathematics teachers' confidence and instructional quality, ultimately benefiting student learning outcomes. Thus, it calls for a deeper investigation into this triadic relationship to support evidence-based strategies for teacher empowerment and effectiveness.

1.1. Research Objectives

1) To determine the effect of pedagogical content knowledge on mathematics teaching anxiety.

2) To determine the effect of mathematics teachers' efficacy on mathematics teaching anxiety.

3) To examine the moderating effect of mathematics teaching efficacy on the relationship between pedagogical content knowledge and mathematics teaching anxiety.

2. Literature Review and Hypothesis Development

2.1. Pedagogical Content Knowledge and Mathematics Teaching Anxiety

Pedagogical content knowledge (PCK) has long been considered a key component in effective mathematics instruction, as it integrates subject matter knowledge with teaching strategies. According to Lee et al. (2018), PCK is critical for teachers to effectively convey mathematical concepts to students. Recent studies have continued to highlight the significance of PCK in enhancing teachers' confidence and competence in the classroom. A study by Gess-Newsome et al. (2019) emphasized that teachers with a deep understanding of PCK can better manage students' learning processes and reduce classroom challenges. This understanding, in turn, is found to mitigate stressors that contribute to anxiety among mathematics teachers. As teachers develop stronger PCK, they are more likely to experience less anxiety, since they can anticipate and address students' misconceptions with greater ease (Filgona et al., 2020).

Mathematics teaching anxiety has been a subject of increasing concern, as it negatively impacts both teacher performance and student learning outcomes. Various studies have shown that anxiety, especially math anxiety, can hinder teachers' ability to deliver effective instruction. In a study conducted by Gresham (2018), the researchers found that teachers who experience high levels of mathematics anxiety often struggle with teaching complex mathematical topics, which can negatively affect their pedagogical decisions.

Recent research has also explored the potential relationship between PCK and anxiety in mathematics teaching. Studies suggest that teachers' anxiety levels may be influenced by their perceived lack of PCK. For example, a study by Smit et al. (2017) revealed that teachers with lower PCK reported higher levels of anxiety, particularly when faced with teaching challenging content. In contrast, teachers who felt more prepared due to their strong PCK showed less anxiety and were more equipped to handle the pressures of teaching mathematics. The interplay between these two factors highlights the importance of professional development programs to enhance PCK, which, according to Dong et al. (2020), could help alleviate anxiety among mathematics teachers and promote a more positive teaching experience. The first hypothesis is thus established as:

H1: Pedagogical content knowledge positively influences mathematics teaching anxiety

2.2. Mathematics Teaching Efficacy and Mathematics Teachers’ Anxiety

Mathematics teaching efficacy, defined as teachers' belief in their ability to teach and support students in learning mathematics effectively, has been widely studied for its impact on teaching quality and student achievement. Studies have shown that higher levels of teacher efficacy are linked to improved teaching practices and better student outcomes. For instance, Nurlela et al. (2022) found that teachers with high efficacy tend to employ more effective instructional strategies, which in turn enhance students' problem-solving skills and academic performance. Research by Boeve-de Pauw et al. (2022) suggests that teachers' self-efficacy is shaped by their previous success, ongoing professional development, and support systems. Furthermore, Wang and Pan (2023) argue that teacher efficacy influences the approach teachers take to classroom management and their emotional resilience, directly affecting student engagement in mathematics.

Mathematics teaching anxiety has been a growing concern in education, as it negatively impacts their performance and the learning environment they create for students. According to Ozben and Kilicoglu (2021), mathematics anxiety among teachers is linked to feelings of inadequacy in handling mathematical content and students' needs. Teachers with high anxiety often experience stress during lesson delivery, which can impair their ability to effectively communicate mathematical concepts. The presence of anxiety in teachers is a significant barrier to their professional development and affects their pedagogical practices, limiting their capacity to inspire students to engage with mathematics confidently.

A growing body of literature has examined the interaction between mathematics teachers' efficacy and anxiety, highlighting how these two factors influence one another. Tassell et al. (2020) found that teachers with higher efficacy tend to experience lower levels of anxiety, as their confidence in their ability to manage and teach mathematics mitigates stress. Conversely, Zee and Koomen (2016) identified that high levels of mathematics anxiety may diminish teachers’ perceived efficacy, creating a negative feedback loop that affects both teacher well-being and student outcomes. Furthermore, research by Kanadlı (2017) suggests that fostering teachers' self-efficacy through professional development and peer support can help reduce their anxiety, creating a more effective and supportive learning environment for both teachers and students. The second hypothesis is thus established as:

H2: Mathematics teachers' efficacy positively influences mathematics teaching anxiety.

2.3. Moderating Effect of Mathematics Teaching Efficacy

The relationship between pedagogical content knowledge (PCK) and mathematics teaching anxiety has been well-documented in research, highlighting the importance of teachers' subject-specific knowledge in alleviating feelings of anxiety in the classroom. PCK, which refers to the ability to integrate content knowledge with effective teaching strategies, is considered a key factor in enhancing teaching practices and reducing teacher stress. Teachers with high levels of PCK tend to be more confident in their instructional practices, which can, in turn, reduce anxiety related to classroom management and content delivery. Studies have shown that effective pedagogical strategies, backed by solid content knowledge, provide teachers with a sense of control, which helps in managing stressful teaching situations (Franklin & Harrington, 2019; Li et al., 2022). Moreover, teachers with lower PCK are more likely to experience anxiety, as they struggle with both understanding the subject matter and delivering it effectively to students.

Mathematics teaching efficacy, which refers to teachers' beliefs in their ability to teach mathematics effectively, has been found to play a significant moderating role in the relationship between PCK and mathematics anxiety. Research suggests that teacher efficacy can buffer the negative effects of anxiety by enhancing teachers' confidence in their teaching abilities (Fathi & Derakhshan, 2019). Teachers with high efficacy are less likely to be affected by anxiety because they believe in their capacity to engage students and overcome teaching challenges. According to a study by Wang et al. (2024), teacher efficacy is positively correlated with reduced anxiety, as teachers with a strong sense of efficacy are more resilient in the face of teaching challenges. In contrast, teachers with low efficacy are more vulnerable to experiencing anxiety, particularly when their PCK is insufficient.

Recent studies have explored how mathematics teaching efficacy moderates the relationship between PCK and mathematics anxiety. For example, a study by Smit et al. (2017) highlighted that high teacher efficacy could mitigate the negative impact of low PCK on teacher anxiety, and enable teachers to apply adaptive teaching strategies. Additionally, evidence from research by Cardullo et al. (2021) and Çetin & Yazlık (2022) suggests that the interaction between teacher efficacy and PCK is crucial for reducing anxiety in mathematics teachers, particularly in high-stakes teaching environments. As such, developing both PCK and teacher efficacy should be central to professional development programs aimed at minimizing teacher anxiety and improving overall teaching effectiveness in mathematics education. The third hypothesis is thus established as:

H3: Mathematics teaching efficacy positively moderates the relationship between pedagogical content knowledge and mathematics teaching anxiety.

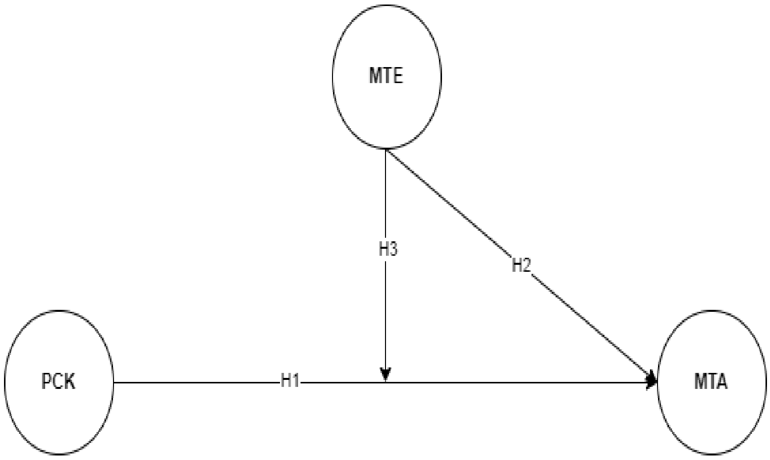

Figure 1. Conceptual Framework

3. Method

3.1. Sample and Data Collection

The study focused on in-service mathematics teachers as its sample. Initially, the target population comprised 281 in-service mathematics teachers drawn from a target pool of 950 teachers. However, by the end of the four-week data collection period, 249 valid questionnaires were successfully retrieved. Before administering the questionnaire, the researcher sought permission from individual instructors working in senior high schools in Kumasi, Ghana. The data collection process adhered to ethical considerations and ensured that all participants willingly in the study.

Convenience sampling was employed to select respondents. This method involved engaging teachers who were present during the data collection period and willing to complete the questionnaire. Convenience sampling was chosen for its practical advantages, including cost-effectiveness, time efficiency, and ease of implementation, as noted by Etikan (2017). This approach enabled the researchers to gather data within a limited timeframe while minimizing logistical challenges.

The sample size was determined out of the population of about 950 in-service mathematics teachers from senior high schools in Kumasi; using Yamane's (1967) formula which is indicated as follows;

$$n = \frac{N}{1 + Ne^2}$$

where N denotes the population size, n denotes the sample size, and e is the significant level. A 95% confidence interval was selected for the study with a 5% margin of error. Based on this, the sample size was computed using the formula, N = 950, and e = .05. Therefore,

$$n = \frac{950}{1 + 950(0.05)^2} = 281.481 \approx 281$$

Therefore, a sample size of 281 was deemed sufficient for the study.

The researcher employed a structured questionnaire as the primary research instrument, which was printed and administered with the help of a trained research assistant. The structured format of the questionnaire ensured that all participants responded to the same set of questions in a consistent manner, which is crucial for maintaining uniformity in the data collection process. The use of trained research assistants facilitated the efficient distribution and collection of the questionnaires, ensuring that participants understood the questions and followed the correct procedures. This approach also helped to minimize potential errors in the administration process, providing a controlled environment for gathering data.

The decision to use a structured questionnaire was based on several key advantages it offers in research. According to Mathiyazhagan (2010), a structural questionnaire enhances the reliability of the study by ensuring that responses are consistent across participants. It simplifies data analysis by producing clear, specific answers that can be easily coded and interpreted. Additionally, it minimizes researcher bias, as the standardized questions reduce the influence of personal judgment on the responses. The format also allows for comparative studies, as it ensures that all participants are asked the same questions, which is vital for drawing meaningful comparisons across different groups or contexts.

3.2. Ethical Consideration

To ensure the credibility of the data and adherence to ethical research standards, several critical measures were implemented. First, ethical approval was obtained from the relevant institutional review boards of the author's affiliated institution. This approval process ensured that the research adhered to established ethical guidelines, including consideration for obtaining informal consent, safeguarding data, and protecting respondents' privacy against unauthorized access. These steps were vital to maintain the integrity of the research and uphold the trust and rights of all participants involved.

Respondents were thoroughly briefed on the study's purpose through a detailed cover letter attached to the questionnaire they received, this letter outlines the goals of the study, the voluntary nature of their participation, and the measures taken to ensure their confidentiality and anonymity. Participants were assured that their responses would remain secure and their identities would not be disclosed. Furthermore, they were informed of their right to withdraw from the study at any time without any repercussions. These measures collectively aimed to foster a sense of trust, transparency, and respect for the participants, ensuring their comfort and willingness to contribute authentic and unbiased data to the research.

3.3. Questionnaire and Measures

This study focused on three primary variables: pedagogical content knowledge, mathematics teaching efficacy, and mathematics teaching anxiety (see Appendix A). These variables were evaluated using a five-point Likert scale, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). The scale allowed participants to express varying degrees of agreement or disagreement with specific statements related to each variable. Pedagogical content knowledge measures the depth of teachers' understanding of mathematical concepts and their ability to convey this knowledge effectively in a classroom setting. Mathematics teaching efficacy assessed teachers' confidence in their ability to teach mathematics successfully, while mathematics teaching anxiety captured the level of apprehension or stress experienced by teachers when teaching mathematics.

The items used to assess these variables were adapted from established instruments to ensure validity and reliability. Specifically, the statement measuring pedagogical content knowledge was drawn from Bakar et al. (2020). These items were; *"I am confident in my ability to explain mathematical concepts clearly to students", "I can anticipate the types of errors students are likely to make when learning mathematics", "I am familiar with the curriculum standards for teaching mathematics at any grade level", "I am skilled at developing assessment tasks that align with the mathematical content taught", and "I can identify when students have misconceptions about mathematical concepts and address them effectively"*. Similarly, the items for mathematics teaching efficacy were adapted from Twohill et al. (2023). These items were*; "I can effectively address students' questions about mathematics, even when they are challenging", "I can create engaging mathematics lessons that enhance students' understanding", and "I feel capable of using real-world examples to make mathematics relevant to students"*. Moreover, those for mathematics teaching anxiety were adapted from Patkin and Greenstein (2020). These items were; "*I feel anxious when I am preparing mathematics lessons for my students", "I worry about my students not understanding the mathematical concepts I teach", "I feel worried about preparing and grading mathematics assessment accurately", "I feel uneasy about being observed or evaluated while teaching mathematics", "I feel stressed when students ask unexpected or challenging mathematical questions during class", and "I feel overwhelmed by the amount of time needed to effectively teach mathematics concepts".* By adapting previously validated questionnaires, the study ensured the robustness of the measurement tools while tailoring them to suit the research context. These adapted instruments provided a comprehensive framework for collecting data to explore the relationship between the three variables.

The study chose to adapt an existing questionnaire rather than develop a completely new one. This decision was guided by the need to enhance the reliability and validity of the measurement instruments, leveraging the proven accuracy of previously validated tools. By using an established questionnaire, the study ensured consistency with prior research, which facilitates the comparison of findings across different studies. Additionally, adapting existing instruments strengthens both content validity, that is ensuring the questionnaire adequately covers all aspects of the constructs, and construct validity, which also ensures the tools effectively measure what is intended to measure.

As Rogoda et al. (2022) noted, using validated measurement scales from prior empirical studies can simplify the process of creating and validating new instruments. This approach reduces the items and effort required for developing original measurement items while maintaining a high level of accuracy. Although the items were derived from earlier studies, modifications were made to ensure they were contextually relevant and aligned with the objectives of the present study. This adjustment helped the questionnaire reflect the specific constructs being investigated while preserving the robustness and reliability of the original tools.

3.4. Analysis of Validity and Reliability

Before conducting the path analysis, several preliminary analyses were performed to ensure the validity and reliability of the measurement items used to assess the constructs in the study. These analyses were crucial for determining whether the measurement instruments adequately captured the intended constructs and provided meaningful data. The first step involved performing a Confirmatory Factor Analysis (CFA) using Amos (v.23) software. CFA is a robust statistical method used to test the hypothesized factor structure of a set of observed variables, ensuring that the items are loaded appropriately onto their respective factors. The results of CFA are presented in Table 1 and Figure 2, which provide a clear overview of how well the measurement items fit the proposed model. As part of the CFA process, measurement items that demonstrated factor loadings below .5 were removed from the analysis. This threshold was adopted in line with establishment practices in previous studies, such as those by Dogbe et al. (2020) and Asare et al. (2024), which suggest that factors loading below this value are too weak to contribute meaningfully to the construct being measured. Removing these items helped to improve the overall validity of the model. This process of item refinement is essential for enhancing the robustness of the research findings and ensuring that the subsequent path analysis is based on a strong and reliable measurement model.

To ensure the internal consistency of the measurement scales used in the study, Cronbach's Alpha (CA) analysis was conducted using SPSS (v.23) software. Cronbach's Alpha is a widely used statistic to assess the reliability of a scale, with values ranging from 0 to 1. A higher value indicated better internal consistency, with a value of .7 or above commonly regarded as accepted. This analysis helps confirm whether the items within a particular scale are measuring the same underlying concepts, ensuring the validity of the results. The results of the Cronbach's Alpha analysis for key variables in the study showed strong internal reliability. Specifically, the scale for mathematics teaching efficacy recorded a Cronbach's Alpha score of .859, indicating high reliability. Similarly, the scale for pedagogical content knowledge and mathematics teaching anxiety showed even higher values, with scores of .935 and .934, respectively. These values suggest that the measurement instruments used for these constructs exhibit excellent internal consistency, confirming the reliability of the data used in the study.

To assess convergent validity, Average Variance Extracted (AVE) was computed using the standardized factor loadings of the retained measurement items. Convergent validity indicates the extent to which a set of measurement items consistently represents a single construct. According to Fornell and larcker (1981), for convergent validity to be considered acceptable, the Composite Reliability (CR) should have a minimum value of .7, while the AVE should be at least .5. These criteria ensure that the measurement model accurately reflects the underlying constructs by indicating that the items within each construct share a substantial amount of variance. Based on the results shown in Table 1, the AVE values for the constructs were generally satisfactory, with the lowest value being .714 for the construct of mathematics teaching anxiety. This indicates that mathematics teaching anxiety met the required threshold for convergent validity. In terms of composite reliability, the lowest score recorded was .915 for the construct of mathematics teaching efficacy, which also exceeds the minimum threshold of .7. These findings suggest that the measurement model demonstrates acceptable convergent validity, as both AVE and CR scores are within the required range, ensuring that the constructs are well represented by their respective measurement items.

Hair et al. (2010) and Arthur (2022) provided specific guidelines for evaluating the goodness of fit in structural equation modeling (SEM). According to their recommendations, the Root Means Square Error of Approximation (RMSEA) and the Root Mean Square Residual (RMR) should both be lower than .08, indicating a good fit between the model and the observed data. In addition, the Tukey-Lewis Index (TLI) and the Comparative Fit Index (CFI) should be greater than .9, suggesting that the model explains the relationship between variables well relative to the null model. Lastly, the Chi-Square/Degree of Freedom should ideally be below 3, reflecting an acceptable balance between the model's complexity and its for to the data. As presented in Table 1, the results confirm that the dataset meets these criteria, indicating that the model is an appropriate fit for the data. All of the model provides a reliable and valid representation of the relationships between the variables. This suggests that the structural equation model adequately captures the underlying patterns in the data and is suitable for further analysis.

Table 1. Assessment of Confirmatory Factor Analysis

MFI: CMIN = 81.554; DF = 49; p-value = .002; CMIN/DF = 1.664; TLI = .981; CFI = .986; NFI = .965; RMR = .041; RMSEA = .056; AGFI = .910; GFI = .943; PClose = .311;	Std. Estimate
Pedagogical Content Knowledge: AVE = .802; CR = .942; CA = .935	
PCK2: I am confident in my ability to explain mathematical concepts clearly to students	.882
PCK3: I can anticipate the types of errors students are likely to make when learning mathematics	.886
PCK4: I am familiar with the curriculum standards for teaching mathematics at any grade level	.928
PCK5: I am skilled at developing assessment tasks that align with the mathematical content taught	.886
Mathematics Teacher Efficacy: AVE = .783; CR = .915; CA = .859	
MTE2: I can effectively address students' questions about mathematics, even when they are challenging.	.874
MTE3: I can create engaging mathematics lessons that enhance students' understanding.	.915
MTE4: I feel capable of using real-world examples to make mathematics relevant to students.	.865
Mathematics Teacher Anxiety: AVE = .714; CR = .935; CA = .934	
MTA3: I feel anxious when I am preparing mathematics lessons for my students.	.854
MTA4: I worry about my students not understanding the mathematical concepts I teach.	.879
MTA5: I feel worried about preparing and grading mathematics assessments accurately.	.914
MTA6: I feel uneasy about being observed or evaluated while teaching mathematics.	.872
MTA7: I feel stressed when students ask unexpected or challenging mathematical questions during class.	.781

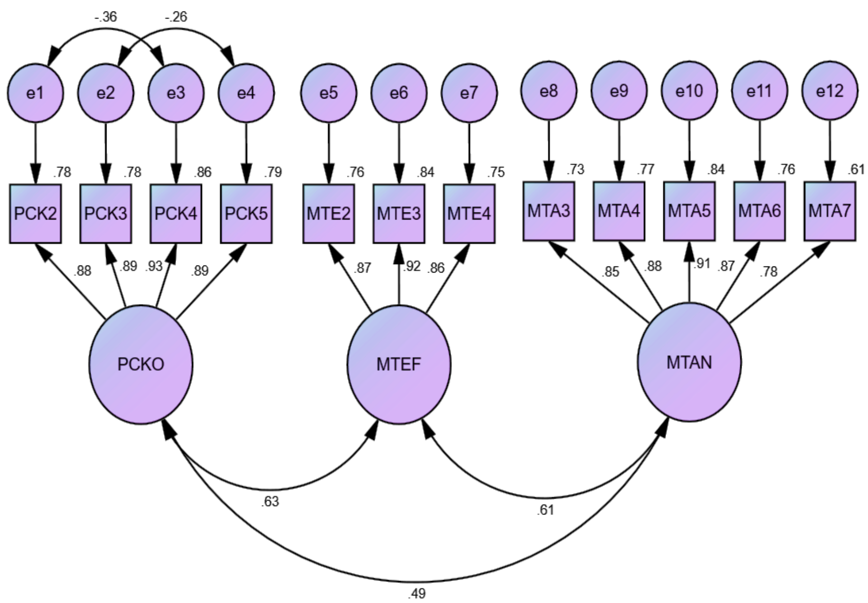

Figure 2. Confirmatory Factor Analysis

Table 2 presents the results of the discriminant validity assessment. Discriminant validity was evaluated by comparing the correlation coefficients with the square roots of the Average Variance Extracted (AVE), following the guidelines of Bamfo et al. (2018) and Edo & Asare (2024). For discriminant validity to be established, the highest correlation must be less than the lowest square root of the AVE. In this study, the lowest $\sqrt{AVE}$ was .861, while the highest correlation coefficient was .661, demonstrating that the constructs were distinct and not highly related to other variables.

Furthermore, the absence of multicollinearity was confirmed, as well correlation coefficients were below the threshold of .7. This indicates that there were no strong associations between the variables, ensuring the reliability of the constructs and the validity of the measurement model. The results affirm that the items measuring each construct were not strongly correlated with items of other variables, supporting the attainment of discriminant validity.

Table 2. Assessment of Discriminant Validity

Variables	CR	AVE	PCKO	MTEF	MTAN
PCKO	.942	.802	***.896***		
MTEF	.915	.783	.633***	***.885***	
MTAN	.935	.714	.494***	.661***	***.861***

* ~ P-value significant at 1% (.01); * ~ P-value significant at 5% (.05); √AVE are bold and underlined

3.5. Mathematical/Regression Equation

For a simple moderating model as presented in Figure 1, i[th] $(1 \leq i \leq n)$ is given as follows:

$$Q_i = \alpha + \beta_\alpha X_i + \varepsilon_{Q_i}$$

$$tT_i = \alpha + \beta_b Q_i + \beta_g X_i + \varepsilon_{T_i}$$

To formulate mathematical equations for hypotheses, it's essential to align them with the research objectives and variables. Below is a generalized structure for presenting hypotheses using equations:

H1: Pedagogical content knowledge positively influences mathematics teaching anxiety.

$$MTA_i = \alpha + \beta_\alpha PCK_i + \varepsilon_{MTA_i}$$

H2: Mathematics teachers' efficacy positively influences mathematics teaching anxiety.

$$MTA_i = \alpha + \beta_\alpha MTE_i + \varepsilon_{MTA_i}$$

H3: Mathematics teaching efficacy positively moderates the relationship between pedagogical content knowledge and mathematics teaching anxiety.

$$MTA_i = \alpha + \beta_\alpha PCK_i + \beta_\alpha MTE_i + \beta_\alpha (PCK\_MTE)_i + \varepsilon_{MTA_i}$$

The interaction term $\beta_\alpha (PCK\_MTE)_i$ indicates moderation.

4. Results

Amos (v.23) was utilized to conduct the path analysis, employing covariance-based structural equation modeling (SEM). The analysis was performed at a 95% confidence level with 5000 bootstrap samples, applying the Bias-Corrected (BC) percentile method of bootstrapping to ensure rebuts statistical inference.

The results of the analysis are presented in Table 3. Additionally, the structural model, which visually represents the relationships among the variables, is illustrated in Figure 3. These findings provide valuable insights into the hypothesized relationships with the model.

For the hypothesized paths, pedagogical content knowledge had a significant direct positive effect on mathematics teaching anxiety ($\beta = .204; p < .05$). The finding indicates that teachers with strong pedagogical content knowledge experience a noticeable increase in mathematics teaching anxiety, suggesting a direct positive relationship. This implies that while expertise in pedagogy and content enhances teaching ability, it may also heighten awareness of challenges, leading to increased anxiety in teaching mathematics. H1 was therefore accepted by this study.

Results showed that mathematics teaching efficacy had a direct positive effect on mathematics teaching anxiety ($\beta = .548; p < .01$). This means that mathematics teaching efficacy influences mathematics teaching anxiety positively, with a standardized regression coefficient (β) of .548. In other words, as mathematics teaching efficacy increases, mathematics teaching anxiety also tends to increase, and this effect is statistically significant at a p-value less than .01. H2 is therefore accepted by this study.

Table 3. Direct Path Estimates

Path Summary	Std. Estimate	Std. Error.	Critical Ratio	***p*-value**
MTE→MTA	.548	.093	5.905	***
PCK→MTA	.204	.089	2.286	.022
PCK_MTE→MTA	.208	.056	3.714	.023

Finally, the researcher hypothesized that mathematics teaching efficacy moderates the relationship between pedagogical content knowledge and mathematics teaching anxiety. From Table 3, the research realized that both PCK and mathematics teaching efficacy had a direct positive effect on mathematics teaching anxiety. The interaction variable (PCK_MTE) also had a positive effect on MTA. Figure 3 shows that, at the higher level of mathematics teaching anxiety (yellow line), the effect of PCK on mathematics teaching efficacy becomes greater, H4 was thus supported by the analysis.

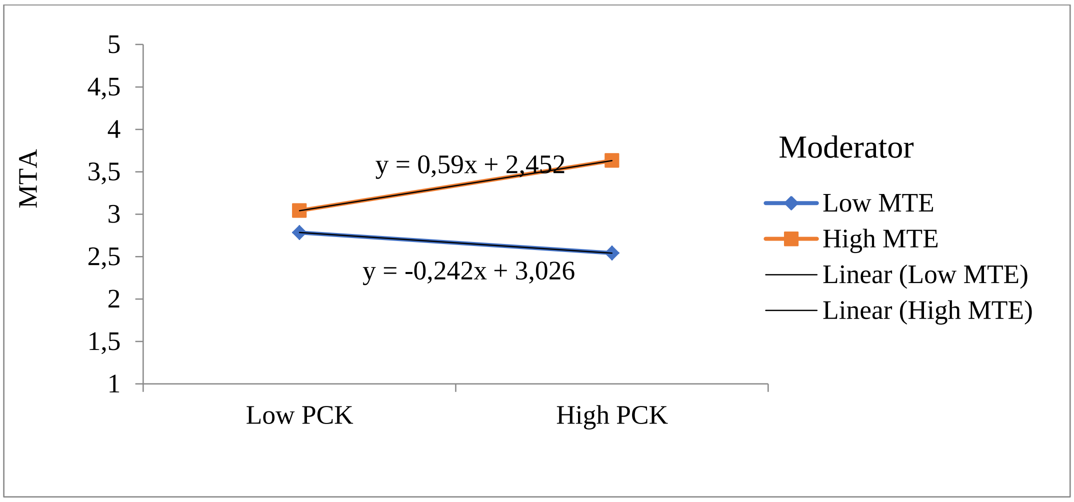

Figure 3. Two-way Interaction Illustration for Moderating Effect

The interactive term pedagogical content knowledge and mathematics teaching efficacy (PCK_MTE) had a significant positive effect on mathematics teaching anxiety. The interactive term **pedagogical content knowledge and mathematics teaching efficacy (PCK_MTE)** refers to the combined influence of a teacher's deep understanding of mathematics content and the ability to effectively teach it, alongside their confidence in their teaching capabilities. This interaction had a positive and significant effect on mathematics teaching anxiety, indicating that as PCK and MTE improve simultaneously, the anxiety associated with teaching mathematics may increase rather than decrease. This counterintuitive finding might suggest that teachers with high PCK and MTE are more aware of the complexities and challenges in teaching mathematics, potentially heightening their anxiety. Figure 3 shows that mathematics teaching efficacy (MTE) strengthens the positive relationship between pedagogical content knowledge and mathematics teaching anxiety.

5. Discussion

This section provides a discussion of results, in line with the study's hypotheses.

5.1. Hypothesis one (H1): Pedagogical content knowledge positively influences mathematics teachers' anxiety

The study revealed that pedagogical content knowledge (PCK) has a statistically significant positive effect on mathematics teaching anxiety. This finding underscores the critical role that teachers' knowledge of both mathematical content and pedagogy plays in shaping their anxiety levels when teaching mathematics. The positive coefficient suggests that as teachers develop their PCK, their teaching anxiety decreases. This finding aligns with the study by Aksu and Kul (2019), whose findings indicated that a high level of PCK positively influenced pre-service teachers' MTE. Moreover, Reid et al. (2018) analyzed the math content knowledge and math anxiety level of 99 elementary teachers' candidates. Their study used mixed-method research via quantitative instruments. The result from their study revealed a strong negative correlation between MA and MCK. By linking PCK to anxiety reduction, this study contributes to a more nuanced understanding of how professional knowledge affects emotional states in teachers.

From a theoretical perspective, this finding aligns with Shulman's (1986) model of teachers' knowledge, which emphasizes the integration of content and pedagogy as foundational for teaching excellence. The significant effect of PCK on mathematics teaching anxiety also resonates with the self-efficacy theory proposed by Bandura (2006), which suggests that confidence in one's skills (in this case, PCK) reduces anxiety. Teachers with high PCK likely perceive themselves as more capable of managing classroom challenges, reducing their susceptibility to anxiety.

5.2. Hypothesis two (H2): Mathematics teachers' efficacy positively influences mathematics teachers' anxiety

The study revealed a statistically significant and direct positive effect of mathematics teaching efficacy on mathematics teaching anxiety. This finding underscores the critical role of teaching efficacy in influencing the emotional and cognitive aspects of teaching mathematics. The result aligns with Bandura's (1986) self-efficacy theory, which posits that individuals with higher self-efficacy are better equipped to handle challenges and perform tasks with greater resilience and less emotional distress. In this study, teaching efficacy serves as a buffer against the stressors that typically exacerbate teaching anxiety. The implications of this finding are far-reaching, particularly in the context of teacher education and professional development programs. This finding is consistent with prior studies. For example, Han et al. (2021) found a strong inverse relationship between teaching efficacy and teaching-related stress. Zakariya and Wardat (2023) demonstrated that mathematics teaching efficacy is a critical determinant of job satisfaction and emotional well-being. Moreover, the findings align with the study of Ebora and Pasia (2023). Their study revealed that mathematics teaching efficacy positively influences mathematics teaching anxiety. Further, Sloan et al. (2002) study investigated the relationship between mathematics anxiety and mathematics teachers' efficacy among 28 elementary preservice teachers at a mid-size university in the southeastern United States. Their findings revealed a significant, moderate negative relationship between mathematics anxiety and mathematics teacher efficacy ($r = -.440$; $p < .05$). Similarly, Zhou et al. (2020) found that self-efficacy negatively influenced math anxiety with an effect size of -.108. However, the current study extends the findings by focusing specifically on the relationship between teaching efficacy and teaching anxiety in mathematics, a subject notorious for its unique stressors.

5.3. Hypothesis three (H3): Mathematics teacher efficacy positively moderates the relationship between pedagogical content knowledge and mathematics teachers' anxiety

The study revealed that both pedagogical content knowledge (PCK) and mathematics teaching efficacy (MTE) have a direct and positive effect on mathematics teaching anxiety (MTA), with the interaction variables (PCK_MTA) also showing a positive impact. These findings highlight the multifaceted nature of teaching anxiety, emphasizing the importance of both teachers' knowledge and their confidence in mitigating it. This finding also reinforces Bandura's (1978) self-efficacy theory, which posits that higher levels of efficacy lead to reduced anxiety and improved performance. Teachers with high teaching efficacy are likely to perceive challenges in the classroom as manageable rather than intimidating. The interaction effect of PCK and MTE on MTE provides further insights into how these factors work synergistically to influence teaching anxiety. This finding implies that combining strong content knowledge and confidence in teaching amplifies anxiety reduction more than either factor alone.

Unexpectedly, the interaction variable had a positive effect rather than the anticipated mitigating effect, which suggests that while both PCK and MTE reduce anxiety independently, their combined impact may also introduce complexity in how teachers perceive their roles. These findings align with previous studies, such as those by Zhou et al. (2020), who found that teacher efficacy significantly reduces teaching anxiety. Similarly, Defianty and Wilson (2024) highlighted the importance of PCK in alleviating teacher stress. However, the unexpected interaction effect challenges earlier studies that teach PCK and MTE as purely anxiety-reducing factors without considering their combined dynamics. This study extends the literature by exploring the interplay between these variables, providing a more comprehensive understanding of how they influence teaching anxiety. By investigating the combined effect of PCK and MTE, this study fills a critical gap in the literature. It challenges the notion that these factors always function independently in reducing anxiety. It contributes to a growing body of research advocating for holistic approaches to teacher development. The results emphasize the need for integrated professional development programs that simultaneously address content knowledge and teaching efficacy while also offering support mechanisms to manage anxiety linked to high expectations.

6. Theoretical Contributions

This study provides a nuanced understanding of the antecedents and moderators of mathematics teaching anxiety. By identifying pedagogical content knowledge as a significant predictor, the research enriches existing theoretical frameworks on the psychological and cognitive dimensions of teaching anxiety. The findings suggest that enhancing PCK can directly alleviate teaching anxiety, offering a fresh perspective for anxiety reduction models in educational theory.

Secondly, the study demonstrates that mathematics teaching efficacy not only influences teaching anxiety directly but also acts as a moderator in the relationship between PCK and teaching anxiety. This dual role of teaching efficacy bridges the gap between theories of teachers' confidence and anxiety, creating a more holistic theoretical framework. The study contributes to the conceptualization of teaching efficacy as both an independent and interaction factor in reducing teaching anxiety.

Thirdly, by empirically validating the moderating effect of teaching efficacy, the study expands the theoretical understanding of how teacher-related constructs interact. It suggests that teaching efficacy can amplify the benefits of PCK in mitigating teaching anxiety. This insight enhances theories on teacher development, highlighting the interdependence of knowledge and self-perception in professional growth and emotional well-being.

Finally, the study establishes a theoretical link between cognitive (PCK), affective (teaching efficacy), and emotional (teaching anxiety) components in teaching mathematics. This integrated perspective contributes to the broader field of educational psychology, offering a robust framework that connects teacher knowledge, beliefs, and emotional states. Such a contribution could pave the way for further theoretical refinements in understanding how teachers collectively influence classroom practices.

7. Educational Implication

The findings that pedagogical content knowledge has a direct positive effect on mathematics teaching anxiety suggest the importance of continuous professional development (CPD) for mathematics educators. Teacher training programs should focus on enhancing PCK by integrating subject-specific pedagogy with real-world applications. Workshops and seminars can be designed to help teachers connect mathematical concepts to practical classroom strategies, enabling them to build confidence and reduce anxiety. Educational stakeholders should also invest in mentoring programs where experienced teachers with strong PCK guide novice teachers, helping them develop effective teaching methods that mitigate anxiety. Moreover, schools and districts should establish supportive teaching environments where teachers receive regular feedback and recognition for their teaching efforts. Collaborative teaching models, where teachers co-plan and co-teach lessons, can also foster a sense of shared responsibility and build efficacy. Additionally, incorporating reflective practices such as self-assessment and peer reviews into teacher evaluation processes can help educators identify areas for improvement, thus boosting their confidence and reducing anxiety. Furthermore, Educational policymakers should consider integrating blended learning approaches into teacher training programs that simultaneously enhance PCK and MTE. For example, case-based learning, microteaching sessions, and simulations can provide teachers with opportunities to practice and refine their instructional techniques in a controlled setting. Finally, educational leaders should encourage collaboration between mathematics educators and instructional designers to create teaching resources that align with both pedagogical and content standards, equipping teachers with the tools they need to deliver high-quality instruction with confidence and minimal anxiety.

8. Conclusion, Limitations, and Suggestions for Further Studies

This study investigated the moderating effect of mathematics teaching efficacy on the relationship between pedagogical content knowledge and mathematics teaching anxiety among in-service mathematics teachers in Kumasi, Ghana. The findings revealed that PCK positively and significantly influenced mathematics teaching anxiety, suggesting that teachers' understanding of mathematical concepts impacts their anxiety levels. Additionally, mathematics teaching efficacy was found to directly reduce teaching anxiety and significantly moderated the relationship between PCK and mathematics teaching anxiety, highlighting its crucial role in reducing anxiety linked to PCK. The study's objectives were to assess the direct effects of PCK and teaching efficacy on mathematics teaching efficacy and to explore the moderating role of teaching efficacy. These objectives were fully achieved, as the findings provide clear evidence of the interrelationship between these variables.

These findings have significant implications for both theory and practice. In theory, they extend the understanding of how teaching efficacy can serve as a buffer against the adverse effects of anxiety in the teaching context. For practice, fostering mathematics teaching efficacy through targeted professional development programs can be a strategic approach to alleviating teaching anxiety among mathematics educators, thereby improving teaching effectiveness.

The study, however, has certain limitations. The use of convenience sampling techniques may limit the generalization of the findings to all in-service mathematics teachers. Additionally, the cross-sectional design restricts the ability to infer causality among the studies.

Further research should consider using a longitudinal design to establish causality and explore other potential moderators or mediators, such as teaching experience or emotional intelligence, in the relationship between PCK and teaching anxiety. A longitudinal approach allows for tracking changes in PCK, teaching efficacy, and anxiety over time, offering insights into how improvements in teaching efficacy might mitigate anxiety as teachers gain experience and enhance their PCK. It provides the ability to capture causality and temporal relationships, ensuring that the effects observed are not merely cross-sectional correlations but reflect meaningful developmental trends. Additionally, this design can account for contextual and individual variability, helping to tailor interventions to support mathematics teachers in building confidence and reducing anxiety effectively.

Finally, this study underscores the pivotal role of mathematics teaching efficacy in reducing teaching anxiety and enhancing the application of PCK among in-service teachers. By prioritizing interventions aimed at boosting teaching efficacy, educational stakeholders can significantly improve mathematics instructional quality and teachers' well-being.

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