

**THE IMPACT OF EDUCATIONAL BACKGROUND ON PRIMARY
MATHEMATICS TEACHERS PEDAGOGICAL CONTENT
KNOWLEDGE IN MALAYSIA**

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Abstract: This study examines the influence of educational background on teachers' Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) in the context of primary mathematics education in Malaysia. Using a quantitative approach, survey data were collected from 600 primary school mathematics teachers representing diverse educational qualifications, including certificate, diploma, degree, and postgraduate levels. Descriptive analysis revealed that teachers reported moderate to high levels of perceived CK, PK, and PCK, with Content Knowledge (CK) recorded the highest mean score, followed by PCK and PK. One-way ANOVA and post hoc analyses indicated that only PK varied significantly across educational backgrounds, with certificate-level teachers reporting higher PK compared to those with diplomas, degrees, or postgraduate qualifications. No significant differences were found for CK or PCK, suggesting that these domains may be shaped more by teaching experience and professional development than by formal qualifications. The findings highlight the importance of embedding practical, pedagogy-focused components within degree and postgraduate programs to strengthen PK, while ongoing professional development is essential to consolidate CK and PCK. This study contributes to teacher education literature by underscoring the differential impact of educational background on knowledge domains and providing implications for teacher training programs, policy, and future research in mathematics education.

Keywords: Content Knowledge, Pedagogical Knowledge, Pedagogical Content Knowledge, primary mathematics, educational background.

INTRODUCTION

Primary mathematics education plays a central role in cultivating learners' analytical reasoning, conceptual understanding, and structured problem-solving abilities. Beyond procedural fluency, effective mathematics instruction supports the development of mathematical thinking, representation skills, and meaningful communication of ideas, aligning with the objectives of Malaysia's national curriculum framework (Ministry of Education Malaysia, 2016, 2018; Mullis et al., 2016).

A substantial body of research consistently demonstrates that teacher effectiveness is one of the most influential factors shaping student learning outcomes (Darling-Hammond et al., 2005; Hill et al., 2005). In mathematics education, instructional quality depends not only on teachers' mastery of subject matter but also on their capacity to design, adapt, and implement pedagogically sound learning experiences. These capabilities are commonly conceptualized through the interrelated domains of Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK), which together underpin instructional effectiveness (Ball et al., 2008; Shulman, 1986).

In Malaysia, pathways into teaching vary markedly. Some teachers enrol in the Program Ijazah Sarjana Muda Perguruan (PISMP) at Institut Pendidikan Guru (IPG), while others complete content-specific bachelor's degrees and then obtain postgraduate certifications or enter through diploma or alternative certification routes (Adams & Tan, 2022). These different pathways may influence how teachers acquire and apply CK, PK, and PCK in their classrooms.

While prior studies have examined teachers' content knowledge and pedagogical competencies across qualification levels, much of this literature implicitly assumes a linear relationship between academic attainment and professional teaching knowledge. That is, higher formal qualifications are often presumed to translate into stronger pedagogical expertise. However, emerging research suggests that PK may be shaped less by academic depth and more by practice-based learning, contextual immersion, and sustained classroom experience. This assumption has been questioned in international research showing that pedagogical competence develops through situated participation in teaching practice rather than through academic accumulation alone (Cochran-Smith et al., 2012; Darling-Hammond, 2006). In this regard, the present study does not merely compare knowledge levels across educational backgrounds. It also seeks to interrogate this linear assumption by examining whether higher academic qualifications necessarily correspond to stronger CK, PK, and PCK among public primary mathematics teachers in Malaysia.

PROBLEM STATEMENT

Recent empirical studies emphasise continuing challenges in developing strong professional knowledge among teachers. For instance, preservice mathematics teachers in a Malaysian university were found to have low levels of PCK, with notable gender differences (Mahendran et al., 2021). A study conducted among primary school mathematics teachers in Perak reported significant associations between PCK and teacher efficacy, highlighting ongoing challenges in translating pedagogical knowledge into effective classroom practice (Masri et al., 2021). Broader literature reviews further confirm that teachers' PCK is influenced by individual, professional, and organizational factors, including access to professional development (Sakaria et al., 2023).

Despite these insights, there remains a lack of recent, comprehensive empirical research in Malaysia that systematically assesses primary mathematics teachers' levels of CK, PK, and PCK, and investigates whether these differ according to their educational background. Understanding how preparation pathways affect teacher knowledge domains is essential for guiding teacher education reforms, designing targeted professional development programs, and ultimately improving mathematics teaching quality and student achievement in Malaysia. Therefore, this study aims to assess the levels of CK, PK, and PCK among public primary mathematics teachers in Malaysia, and to determine whether significant differences exist in these knowledge domains based on teachers' educational backgrounds.

RESEARCH QUESTIONS

To address the identified gaps, the study is guided by the following research questions:

1. What are the levels of Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) among public primary mathematics teachers in Malaysia?
2. Are there significant differences in primary mathematics teachers' CK, PK, and PCK levels based on their educational background?

LITERATURE REVIEW

Content Knowledge

Teacher knowledge has long been conceptualized through Shulman's (1986) framework, where CK represents the teacher's mastery of subject matter, including concepts, procedures, and structures. In mathematics, CK allows teachers to explain ideas accurately, recognize connections between topics, and address misconceptions effectively (Hill et al., 2008). A strong foundation in CK ensures that teachers can present abstract mathematical ideas clearly and design tasks that foster deep conceptual understanding among learners. Recent studies confirm that primary mathematics teachers with stronger CK are better positioned to support problem-solving and conceptual reasoning, rather than focusing solely on procedural skills (An et al., 2021). Rahman and Ikhlas (2022) found that levels of CK and PK among primary mathematics teachers in Malaysia varied significantly, with implications for how effectively teachers can translate knowledge into practice. Such findings reinforce the argument that deep CK enables teachers to move beyond procedural teaching toward cognitively demanding instruction (Hill et al., 2005).

Pedagogical Knowledge

Pedagogical Knowledge (PK) refers to general teaching knowledge not tied to specific subject matter, including classroom management, instructional design, assessment, and understanding of how students learn (Grossman, 1990). Teachers with strong PK can adapt lessons, sustain student engagement, and apply effective questioning and feedback strategies. In the Malaysian context, PK is particularly important in fostering student-centered learning under the Kurikulum Standard Sekolah Rendah (KSSR). Empirical findings indicate that stronger PK is associated with greater instructional effectiveness and adaptive teaching practices (Nor & Rashid, 2021). Internationally, researchers also emphasize that PK provides the foundation for teachers to flexibly adjust instructional strategies when faced with different learner needs and contexts (Depaepe et al., 2020).

Contemporary teacher learning theories emphasize that pedagogical knowledge is not acquired solely through formal academic coursework but is constructed through participation in authentic teaching practices. Practice-based learning theory posits that professional knowledge develops through repeated engagement with real instructional tasks, reflection on classroom interactions, and situated problem solving (Cochran-Smith et al., 2012; Darling-Hammond, 2006). Similarly, situated cognition theory argues that knowledge is inherently context-bound, emerging through activity, tools, and social interaction rather than abstract instruction alone (Lave & Wenger, 1991).

Within this perspective, teachers who undergo practice-oriented preparation, such as certificate or alternative training routes, may develop stronger pedagogical knowledge because these pathways emphasize classroom enactment, instructional routines, and immediate application. In contrast, degree and postgraduate programs may privilege theoretical understanding and disciplinary depth, potentially limiting opportunities for sustained pedagogical rehearsal. This theoretical lens provides a useful framework for interpreting differences in pedagogical knowledge across educational backgrounds, particularly in contexts where teachers enter the profession through diverse preparation pathways.

Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK), conceptualized by Shulman (1987), lies at the intersection of CK and PK. It is the specialized knowledge that enables teachers to transform mathematical content into forms accessible to learners, anticipate misconceptions, select representations, and design tasks that scaffold understanding (Ball et al., 2008). PCK has been widely recognized as a strong predictor of instructional quality, especially in mathematics, where abstract concepts often challenge students (Burroughs et al., 2019). Empirical studies in Malaysia have highlighted that while teachers may possess adequate CK, variations in PCK often hinder their ability to translate knowledge into effective practice (Ling & Mahmud, 2023; Rahman & Ikhlas, 2022; Sakaria et al., 2023). These differences are linked to the teachers' educational pathways, as graduates from integrated teacher training programs such as PISMP tend to demonstrate stronger PCK compared to those from alternative routes (Adams & Tan, 2022).

Pedagogical Content Knowledge Framework

Teacher knowledge plays a central role in effective classroom instruction. Building on Shulman's (1986) model of teacher knowledge, this study adopts the PCK framework, focusing specifically on CK, PK, and PCK. While the broader Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006) integrates technological aspects, this study narrows its attention to CK, PK, and PCK to better understand the foundation of effective mathematics teaching.

Shulman (1986) highlighted the importance of teachers possessing not only a strong command of CK but also the PK necessary for effective instruction. CK refers to teachers' depth of understanding of mathematical ideas, including how concepts are structured, interconnected, and sequenced within the curriculum. In contrast, PK reflects teachers' general instructional competence, including lesson planning, classroom organization, assessment practices, and responsiveness to diverse learners. The intersection of these two domains forms PCK, which represents teachers' ability to transform mathematical content into forms that are pedagogically powerful and accessible to learners.

According to Booker (2017) and Depaepe et al. (2013), effective teaching requires the integration of CK and PK, as neither alone is sufficient to ensure student learning. PCK, therefore, becomes the critical link, as it allows

teachers to identify student misconceptions, design meaningful representations of abstract concepts, and employ strategies that make mathematics engaging and comprehensible.

Recent research has highlighted that strong CK and PK are essential for developing high-quality PCK, which directly influences teaching practices and student achievement (Hill et al., 2008; Kleickmann et al., 2013). Although technology integration is an important area in contemporary education, this study focuses on the CK, PK, and PCK, as they remain the foundation upon which effective instructional practices are built.

By examining the levels of CK, PK, and PCK among public primary mathematics teachers, this study seeks to provide insights into the current strengths and gaps in teacher knowledge. These findings can inform professional development programmes, support instructional improvement, and ultimately contribute to enhancing mathematics education at the primary level.

Taken together, the literature shows that effective mathematics teaching relies not only on individual domains of knowledge but also on their integration. Teachers with strong CK but weak PK may struggle to engage students, while those with strong PK but limited CK may lack the conceptual depth to address students' misconceptions. PCK bridges these gaps, positioning teachers to deliver high-quality instruction. However, empirical research in Malaysia continues to report variability in teachers' CK, PK, and PCK, with differences associated with professional and contextual factors, including teacher preparation experiences and access to professional development (Adams & Tan, 2022; Rahman & Ikhlas, 2022; Sakaria et al., 2023). These findings justify the current study's focus on examining the levels of CK, PK, and PCK among public primary mathematics teachers in Malaysia and exploring how educational background influences these knowledge domains.

METHODOLOGY

This study adopted a descriptive research design and used a self-reported survey to gather quantitative data. Based on Creswell and Creswell (2018), surveys give respondents the chance to express their knowledge, attitudes, and opinions about the subject being investigated. The CK, PK, and PCK of both novice and experienced primary mathematics teachers can be assessed in this context through survey research.

Ethical Consideration

Before undertaking educational research in Malaysia, the researcher obtained approval from the Education Planning and Research Division (EPRD) of the Malaysian Ministry of Education and the State Department of Education. After obtaining the approvals, permission was obtained from the corresponding Principals. Before data collection, individuals' consent was also requested.

Instrumentation

The original Technological Pedagogical Content Knowledge (TPACK) instrument was developed by Pamuk et al. (2015) for preservice mathematics teachers and comprised 26 items measuring Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK). To ensure contextual relevance for Malaysian primary mathematics teachers, face and content validity were established through consultations with five practitioner users and nine subject-matter experts. A back-to-back translation process was implemented to maintain linguistic accuracy and conceptual equivalence (Behr, 2017). All items were initially measured on a 10-point Likert scale (1 = strongly disagree to 10 = strongly agree), following Weng (2004). The instrument was also piloted with 150 teachers before the main data collection.

Item reduction was conducted through a systematic, multi-stage validation process during the pilot phase. Exploratory Factor Analysis (EFA) was first applied to examine the underlying factor structure and to identify items with weak loadings, cross-loadings, or conceptual redundancy. Rasch analysis was subsequently used to evaluate item functioning and response category performance, leading to the collapsing of the original 10-point scale into five response categories to improve measurement efficiency. Confirmatory Factor Analysis (CFA) was then conducted on the refined item set, and only items demonstrating strong standardized loadings, conceptual coherence, and stable psychometric properties were retained.

Following this process, the final instrument comprised nine items, with three items measuring each construct (CK, PK, and PCK). Reliability analysis demonstrated excellent internal consistency for the overall scale ($\alpha = .939$) and for the subscales CK ($\alpha = .923$), PK ($\alpha = .946$), and PCK ($\alpha = .958$). Although the reduced instrument reflects a balance between psychometric rigor and construct parsimony, it is acknowledged that PCK is a multidimensional construct and that the retained items represent its core features rather than its full conceptual breadth. It is important to note that the CK, PK, and PCK constructs in this study represent teachers' self-perceived professional knowledge rather than directly observed instructional competence. Self-report measures capture individuals' beliefs about their capabilities, which are particularly relevant when examining professional confidence and perceived readiness to teach. Such measures are widely used in large-scale teacher knowledge research when the focus concerns perceived professional competence rather than observed performance (Klassen & Tze, 2014). Previous research has demonstrated that teachers' self-perceptions of pedagogical competence are meaningfully associated with instructional decision-making, classroom practices, and engagement in professional learning (Bandura, 1997; Klassen & Tze, 2014). Therefore, self-reported measures were considered appropriate for addressing the study's research questions, which focus on perceived knowledge differences across educational backgrounds.

Population and Sample

This study was conducted between November and December 2021, and data were collected from teachers in national primary schools in Malaysia. The participants' teaching experience ranged from one year to more than 31 years, and they taught mathematics at levels from Standard 1 to Standard 6. From the onset, it was clear that the instrument for the study was relevant to the target group of participants. A probability multi-stage cluster sampling design was employed to ensure representativeness of the large population of Malaysian primary mathematics teachers. Sampling was conducted in four stages: zones, states, districts, and schools. One state was randomly selected from each of the five geographical zones (Pulau Pinang, Melaka, Perak, Terengganu, and Sarawak), followed by the random selection of districts and schools. Mathematics teachers from the selected schools were then invited to participate, producing a final sample of 709 teachers.

Data Collection

In light of movement restrictions during the COVID-19 period, data were gathered electronically using a structured online questionnaire distributed through school networks. The researcher contacted the head of the mathematics panel in each selected school and shared the questionnaire link for dissemination to teachers. Data collection remained open for one month, and informed consent was obtained from all participants. A total of 709 teachers responded, of whom 78 declined participation, yielding a valid response rate of 89%, which is well above the 50% benchmark recommended by Gay et al. (2012). After data cleaning and screening in SPSS version 26.0, 600 responses were retained for analysis.

DATA ANALYSIS AND RESULTS

The data obtained from the questionnaire were analyzed using SPSS version 26.0. To determine the levels of CK, PK, and PCK among public primary mathematics teachers, descriptive statistics, specifically mean scores and standard deviations, were employed. Furthermore, inferential statistical techniques were applied to examine variations in participants' demographic data. To examine the mean significances among the independent samples in this instance, a t-test on independent samples was run. To further analyse age level, which has more than two groups, the researcher used one-way ANOVA.

Descriptive Analysis of Demography

Demographics are the descriptions of a population. For this research, the descriptions of the public primary school Mathematics teachers in Malaysia collected are the gender, age, education level, and the number of years of teaching experience. Table 1 displays the descriptive analysis of the public primary school Mathematics teachers in Malaysia who were the respondents of this research.

Table 1 shows that the participants were of various demographic variables. In regard to gender, there were more female participants ($n=458$, 76.3%) than male participants ($n=142$, 23.7%). As for the age, 28(4.7%) in-service mathematics teachers were in the range of 20 – 30. Among the respondents, 194 mathematics teachers (32.3%) were aged between 31 and 40 years, while 277 teachers (46.2%) fell within the 41–50 age group. Additionally,

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101 teachers (16.8%) were between 51 and 60 years old. In terms of teaching experience, 278 school mathematics teachers (46.3%) reported having 11 to 20 years of experience. Furthermore, 32.7% of public primary school mathematics teachers indicated 21 to 30 years of teaching experience, whereas 14.3% stated they had between 0 and 10 years of experience. This data indicates that the public primary school Mathematics teachers in this research are teachers with more than ten years of service, and only 40(6.7%) teachers have served for more than 31 years.

Based on the education level of the public primary school, Mathematics teachers with a Bachelor's degree are the highest group of school Mathematics teachers (82%). Further, 3.0 per cent of the school's Mathematics teachers have a Certificate of Teaching, and 7.2 per cent have a Diploma in Teaching. There are 47 school Mathematics teachers who claimed that they have a Master's/PhD (7.8%).

Descriptive Analysis

To assess the level of knowledge, the researchers followed the approach outlined by Best and Khan (1998), categorizing the mean scores into three groups (see Table 2). This classification was based on the total range between the highest and lowest possible scores (6 minus 1 equals 5). Dividing this range by three yielded an interval of approximately 1.67. Based on Table 3, Content Knowledge (CK) recorded the highest mean score ($M = 4.88$, $SD = 0.692$), followed by Pedagogical Content Knowledge (PCK) with a mean of 4.78 ($SD = 0.628$), and Pedagogical Knowledge (PK) with a mean of 4.71 ($SD = 0.631$).

Table 1
Demographic Characteristics of the Respondents

Profile	Frequency N=600	Percentage %	Cumulative %
1. State			
Melaka	94	15.7	15.7
Perak	99	16.5	32.2
Pulau Pinang	129	21.5	53.7
Sarawak	143	23.8	77.5
Terengganu	135	22.5	100.0
2. Gender			
Female	458	76.3	76.3
Male	142	23.7	100.0
3. Age Group			
20 – 30 years	28	4.7	4.7
31 - 40 years	194	32.3	37.0
41 – 50 years	277	46.2	83.2
51 – 60years	101	16.8	100.0
4. Teaching Experience			
0 - 10 years	86	14.3	14.3
11- 20 years	278	46.3	60.6
21- 30 years	196	32.7	93.3
31 years and above	40	6.7	100.0
5. Education Level			
Certificate	18	3.0	3.0
Diploma	43	7.2	10.2
Degree	492	82.0	92.2
Masters/PhD	47	7.8	100.0

Table 2
Categorization of Levels According to Mean Values.

Weighted Average	Result Interpretation
1.00 – 2.50	Low
2.51 – 4.50	Moderate
4.51 – 6.00	High

Table 3

Descriptive Statistics for CK, PK and PCK.

No	Sub-Constructs	Mean	SD	Interpretation
1.	Content Knowledge (CK)	4.88	0.659	High
2.	Pedagogical Knowledge (PK)	4.71	0.631	High
3.	Pedagogical Content Knowledge (PCK)	4.78	0.628	High

Table 4 shows the analysis of response frequencies, indicating consistently high levels of agreement across all constructs. For CK, 76.8% of teachers agreed or strongly agreed that they had sufficient mathematical knowledge (CK1), 68.2% reported being able to explain concepts, formulas, and definitions in depth (CK2), and 75.0% stated they could explain the importance of specific topics (CK3). For PK, agreement was also strong: 70.3% of teachers indicated they could use a variety of approaches to assess learning (PK1), 61.0% reported knowledge of different pedagogies (PK2), and 61.1% acknowledged knowledge of various teaching components such as instruction and assessment (PK3). Regarding PCK, 71.5% agreed or strongly agreed that they could select appropriate content for students' levels (PCK1), 67.0% reported being able to teach subject matter across different levels (PCK2), and 62.5% indicated the ability to identify students' preconceptions and misconceptions (PCK3). Across all items, disagreement was minimal, with less than 5% of teachers selecting negative response options. These findings suggest that teachers held consistently positive self-perceptions of their CK, PK, and PCK.

Table 4

The Results in Frequencies and Percentages

Name of Construct	Item	Frequency (Percentage) of Responses					
		Strongly Disagree (1)	Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Agree (5)	Strongly Agree (6)
CK	CK1: I have sufficient mathematical knowledge.	0	0 (0.0%)	20 (3.3%)	147 (24.5%)	314 (52.3%)	119 (19.8%)
	CK2: I can explain in-depth the concepts, formulas, and definitions in mathematics.	0	1 (0.2%)	20 (3.3%)	170 (28.3%)	310 (51.7%)	99 (16.5%)
	CK3: I can explain why specific topic is important.	0	0 (0.0%)	8 (1.3%)	142 (23.7%)	322 (53.7%)	128 (21.3%)
PK	PK1: I can use a variety of approaches to assess students' learning.	0	0 (0.0%)	18 (3.0%)	172 (28.7%)	332 (57.3%)	78 (13.0%)
	PK2: I have knowledge in different pedagogies of teaching and learning.	0	0 (0.0%)	23 (3.8%)	211 (35.2%)	312 (52.0%)	54 (9.0%)
	PK3: I have knowledge in different components of teaching (i.e., instruction, assessment).	0	0 (0.0%)	21 (3.5%)	212 (35.3%)	311 (51.8%)	56 (9.3%)
PCK	PCK1: I can select teachable content of the subject matter appropriate to students' level.	0	0 (0.0%)	11 (1.8%)	160 (26.7%)	336 (56.0%)	93 (15.5%)

PCK2: I can teach the same subject matter to students at different level.	0	0 (0.0%)	20 (3.3%)	178 (29.7%)	320 (53.3%)	82 (13.7%)
PCK3: I can identify students' preconceptions and misconceptions on the subject matter.	0	0 (0.0%)	16 (2.7%)	209 (34.8%)	308 (51.3%)	67 (11.2%)

Among the three constructs, CK demonstrated the highest levels of agreement, with 76.8% of teachers reporting sufficient mathematical knowledge (CK1) and 75.0% affirming their ability to explain the importance of specific topics (CK3). This was followed by PCK, where 71.5% of teachers agreed they could select appropriate content for students' levels (PCK1). Finally, PK recorded comparatively lower but still strong levels, with 70.3% indicating they could apply varied assessment approaches (PK1).

Primary Mathematics Teachers CK, PK, and PCK by Education Background

A one-way ANOVA was conducted to examine differences in Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) across teachers' education levels. The results showed that there were no significant differences for CK, $F(3, 596) = 1.239$, $p = .295$, or for PCK, $F(3, 596) = 1.581$, $p = .193$. However, a significant difference was found for PK, $F(3, 596) = 3.000$, $p = .030$. The effect size for PK differences was small ($\eta^2 = .015$), indicating that although statistically significant, the practical magnitude of the differences across educational backgrounds was modest. According to Cohen's (1988) guidelines, this represents a small effect size, suggesting limited practical significance despite a statistical difference.

Post hoc comparisons using Tukey's HSD test revealed that teachers with a certificate qualification reported significantly higher PK compared to those with a diploma ($p = .025$), degree ($p = .036$), and master's/PhD ($p = .034$). No other significant group differences were observed for CK or PCK. Descriptive statistics further indicated that the highest mean scores for CK were reported by certificate holders ($M = 5.07$), followed by diploma ($M = 4.89$), degree ($M = 4.88$), and master's/PhD holders ($M = 4.74$). For PK, certificate holders again had the highest mean ($M = 5.11$), followed by degree ($M = 4.71$), master's/PhD ($M = 4.64$), and diploma ($M = 4.61$). In terms of PCK, certificate holders scored highest ($M = 5.04$), followed by degree ($M = 4.79$), diploma ($M = 4.70$), and master's/PhD ($M = 4.70$).

DISCUSSIONS AND CONCLUSIONS

This study investigated the levels of CK, PK, and PCK among public primary mathematics teachers in Malaysia and examined whether these domains differed according to teachers' educational background. Consistent with prior Malaysian research, teachers have reported moderate to high levels of perceived CK, PK, and PCK (Ling & Mahmud, 2023; Rahman & Ikhlas, 2022; Sakaria et al., 2023), suggesting that they possess a reasonable foundation for effective mathematics instruction. However, only PK showed significant variation across educational backgrounds, with certificate-level teachers reporting higher PK compared to their counterparts with diplomas, degrees, or postgraduate qualifications. In contrast, no significant differences were observed for CK or PCK, indicating that these domains may be less influenced by formal academic qualifications and more strongly shaped by classroom experience and professional development (Hill et al., 2008; Kleickmann et al., 2013). Importantly, this pattern challenges the commonly held assumption that higher academic attainment necessarily translates into stronger PK (Darling-Hammond et al., 2005), suggesting instead that pedagogical development may be more closely linked to practice-based and situated professional learning processes (Cochran-Smith et al., 2012; Darling-Hammond, 2006) than to qualification level alone. Conversely, teachers with higher academic qualifications may have been more exposed to theoretical content or subject specialization, but without a proportionate focus on applied pedagogy, which could explain their comparatively lower PK scores. These findings echo Shulman's (1986) assertion that CK and PK develop differently, with PCK emerging as the integrative bridge through actual classroom practice.

Theoretically, this study extends Shulman's framework by demonstrating that the development of pedagogical knowledge is not strictly hierarchical or qualification-dependent, but contextually situated within professional practice. While Shulman conceptualized CK, PK, and PCK as interrelated domains, the present findings suggest that PK may develop more strongly through situated classroom participation than through advanced academic attainment alone. This challenges linear qualification assumptions and contributes to ongoing debates in teacher education regarding the relative roles of academic depth and practice-based immersion in professional knowledge development.

The observed PK differences call into question the assumption that pedagogical competence increases proportionally with academic qualification. From a practice-based learning perspective, this result suggests that PK may be more effectively developed through sustained classroom engagement and routine instructional practice than through advanced academic study alone. Certificate programs in Malaysia often emphasize immediate teaching responsibilities, mentoring, and repeated enactment of instructional strategies, which may accelerate the development of classroom management skills, assessment practices, and adaptive instruction.

Viewed through the lens of situated cognition, PK is constructed through participation in the social and instructional contexts of schooling rather than through decontextualized coursework. Consequently, teachers with higher academic qualifications may possess strong theoretical or disciplinary knowledge without a corresponding advantage in PK if opportunities for situated practice are limited. This finding extends Shulman's framework by illustrating that the development of PK is not strictly hierarchical but contextually contingent, shaped by how and where teachers learn to teach. Specifically, the results suggest that PK may function as a practice-sensitive domain within Shulman's model, developing more strongly through situated enactment than through academic progression alone.

The unexpectedly high PK reported by certificate-level teachers should be interpreted in light of the self-reported nature of the data. Teachers' perceptions of their pedagogical competence may be influenced by confidence gained through sustained classroom engagement rather than by formal academic attainment. Certificate-level teachers typically enter full-time teaching earlier and are immersed in daily instructional practice, which may strengthen their sense of pedagogical efficacy. From a self-perception perspective, frequent successful classroom experiences can reinforce positive judgments of one's pedagogical abilities, even if these are not formally assessed through standardized performance measures. Additionally, teachers with higher academic qualifications may apply more critical self-evaluative standards when responding to survey items, resulting in more conservative self-ratings. This phenomenon has been documented in teacher self-assessment research, where increased theoretical exposure leads to greater awareness of pedagogical complexity and, consequently, lower self-reported competence (Kruger & Dunning, 1999; Kunter et al., 2013). Thus, differences in PK scores may reflect variations in self-perception rather than actual pedagogical superiority.

The results also resonate with Malaysian studies highlighting persistent variations in teacher knowledge domains associated with differences in teacher preparation pathways (Adams & Tan, 2022; Rahman & Ikhlas, 2022). While integrated teacher education programs such as PISMP have been shown to strengthen PCK (Adams & Tan, 2022), this study suggests that practical pedagogical training embedded in certificate-level programs may provide immediate benefits for PK. However, the absence of significant differences in CK and PCK across qualifications indicates that ongoing professional development and classroom experience remain critical for consolidating these domains.

The implications of these findings are threefold. First, Teacher education institutions should integrate longitudinal practicum cycles across qualification levels, including structured mentoring and supervised instructional rehearsal, to ensure pedagogical competence develops alongside disciplinary depth (Darling-Hammond, 2006). Second, professional development initiatives should provide targeted opportunities to strengthen CK and PCK, particularly in areas where teachers may struggle to transform subject matter into effective instructional practices. Third, policymakers should recognize that while higher qualifications contribute to overall teacher professionalism, they may not automatically translate into stronger pedagogical skills without sufficient emphasis on practice and reflection.

Within Malaysia, these findings support ongoing national efforts to strengthen practice-based teacher preparation and continuous professional learning. Teacher education providers, including IPG and public universities, may consider restructuring degree and postgraduate programmes to include longitudinal practicum experiences, structured mentoring, and school–university partnerships that foreground pedagogical enactment alongside academic coursework. Aligning programme design with national teacher professional standards can help ensure that academic advancement and instructional competence develop in an integrated and complementary manner. Such recommendations are consistent with Malaysia’s teacher professional standards and ongoing efforts to strengthen school-based practicum within IPG and university teacher education programmes.

In conclusion, this study contributes to the growing body of knowledge on teacher education in Malaysia by offering empirical evidence on the levels of CK, PK, and PCK among public primary mathematics teachers and their relationship to educational background. The findings suggest that educational background has a differential impact, with significant effects only on PK. While certificate-level teachers may benefit from earlier and more sustained classroom immersion associated with practice-oriented preparation contexts, sustained efforts in both pre-service and in-service contexts are essential to strengthen CK and PCK. By addressing these gaps, teacher education providers and policymakers can enhance the quality of mathematics teaching at the primary level, ultimately supporting improved student learning outcomes. By demonstrating that PK does not increase linearly with academic qualification, this study contributes theoretically by highlighting the central role of practice-based and situated learning in the development of teachers’ professional knowledge.

Several methodological considerations should be noted when interpreting the findings of this study. First, all constructs were measured using self-reported data, which reflects teachers’ perceived knowledge rather than objectively assessed instructional competence. Although self-report instruments are widely used in teacher education research, they may be subject to social desirability and self-perception biases. As such, the findings should be interpreted as indicators of perceived professional knowledge rather than direct measures of classroom practice. Future research should incorporate performance-based assessments, classroom observations, or teaching artefacts to triangulate self-reported data and provide a more comprehensive understanding of teachers’ CK, PK, and PCK.

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