Adoption of Professional Development Innovations in Mathematics Teacher Education: A Systematic Review Guided By the Concerns Based Adoption Model (CBAM)

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ABSTRACT

The effective adoption of professional development innovations such as Professional Learning Communities (PLCs), Pedagogical Content Knowledge (PCK) support, and blended learning in mathematics teacher education remains limited and inconsistent across educational contexts. This study presents a systematic review to examine how these innovations are adopted by mathematics teacher educators and to explain the adoption process using the Concerns Based Adoption Model (CBAM). A PRISMA guided systematic review approach was employed to identify relevant studies published between 2015 and 2025 from Scopus, Web of Science, ERIC, and Google Scholar databases. Following predefined inclusion and exclusion criteria, 48 empirical studies were selected for analysis. Data were extracted systematically and synthesized using thematic analysis guided by the CBAM dimensions of Stages of Concern and Levels of Use. The findings indicate that although awareness of professional development innovations is generally high, meaningful adoption remains limited. Most mathematics teacher educators were positioned at the informational and personal stages of concern, while mechanical and routine levels of use were the most frequently reported implementation patterns. Only a small proportion of studies demonstrated progression toward integration and renewal stages. Compared with blended learning, which was commonly constrained by inadequate digital infrastructure and limited ICT competencies, PLCs and PCK support showed stronger associations with improvements in instructional practices and professional competence. The review further identifies institutional capacity, sustained professional development structures, access to resources, and contextual support systems as major factors influencing successful adoption. The findings suggest the need for stronger institutional support mechanisms and more structured and continuous professional development pathways. Future research should prioritize longitudinal and CBAM informed studies to better understand patterns of sustained adoption in mathematics teacher education.

Keywords: Mathematics Teacher Education, Professional Development, Concerns Based Adoption Model, Professional Learning Communities, Pedagogical Content Knowledge, Blended Learning

INTRODUCTION

The limited success in implementing effective professional development for mathematics teachers remains a global concern, not because such innovations are unavailable, but because their adoption and sustained use remain weak. Education systems increasingly invest in professional development initiatives to strengthen teacher effectiveness, improve pedagogical practices, and support continuous professional learning. However, evidence suggests that these initiatives often fail to achieve their intended outcomes because research and policy

discussions have largely emphasized measurable outcomes such as teacher performance and student achievement, while giving insufficient attention to how teachers engage with and apply professional learning in practice.

As a result, professional development is frequently regarded as effective in theory but demonstrates limited and short-term influence on instructional practice. Emerging evidence indicates that when the transition from teacher intention to actual classroom implementation is not adequately understood, educational change becomes difficult to sustain (Darling Hammond et al., 2020; Desimone & Garet, 2021). This challenge is particularly relevant in mathematics education, where effective teaching depends not only on subject matter expertise but also on the development of pedagogical content knowledge. Such knowledge evolves gradually through sustained engagement in teaching practice, reflection, collaboration, and participation in professional learning environments (Beswick et al., 2023; Korthagen, 2022).

The challenge of adopting professional development innovations is further intensified in African educational contexts by structural and institutional constraints that limit sustained implementation. Across many African higher education systems, professional development activities are commonly delivered through short term, fragmented, and externally supported programmes that often lack continuity, contextual relevance, and follow up support. Consequently, mathematics teachers frequently participate in training activities without adequate opportunities or institutional mechanisms to support classroom implementation.

As a result, teachers may be introduced to approaches such as professional learning communities, pedagogical content knowledge development, and blended learning, yet remain unable to integrate these practices into their teaching. Studies conducted in Sub Saharan Africa suggest that long term adoption of professional development innovations is unlikely in the absence of sustained support structures including mentoring, collaboration, and reflective practice (Luneta, 2022; Oduolowu & Ademola, 2022). Additional barriers such as institutional limitations, inadequate resources, poor technological infrastructure, and restricted internet access continue to hinder the implementation of collaborative and technology supported professional development despite their potential to improve instructional practice and teacher competence (Kafyulilo et al., 2021; UNESCO, 2021).

Although research on teacher professional development continues to expand, there remains limited understanding of how adoption occurs and is sustained over time. Most existing studies focus primarily on relationships between professional development inputs and instructional outcomes, for example examining how training influences teaching quality or how collaborative learning improves practice. Such approaches often assume that professional development follows a linear process in which teachers automatically transform their instructional practice after participation in training. This assumption overlooks the dynamic and developmental nature of adoption, where teachers progress through stages of awareness, engagement, implementation, and sustained use.

Furthermore, limited synthesis exists regarding how mathematics teacher educators adopt major professional development innovations such as professional learning communities, pedagogical content knowledge support, and blended learning within institutional contexts. There is also limited use of systematic reviews grounded in established theoretical frameworks to explain variations in adoption patterns across settings. The Concerns Based Adoption Model (CBAM) provides an appropriate framework for understanding educational change because it explains adoption as a developmental process shaped by teachers' concerns and patterns of use. Despite its relevance, CBAM remains underutilized in synthesizing evidence within mathematics teacher education.

In response to this gap, this systematic review investigates the adoption of key professional development innovations in mathematics teacher education with emphasis on professional learning communities, pedagogical content knowledge, and blended learning. Specifically, the review examines how professional learning communities influence instructional practice, how pedagogical content knowledge contributes to teacher competence, and how blended learning shapes instructional processes. Focusing on these dimensions provides a broader understanding of both the outcomes of professional development and the processes through which instructional change occurs.

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The review adopts the Concerns Based Adoption Model as the guiding conceptual framework to examine how teachers' concerns and levels of use evolve throughout the adoption process. The framework provides a structured approach for understanding how professional development innovations move from awareness to sustained implementation and how this progression influences instructional practice and professional competence (Desimone, 2020; Korthagen, 2022).

This review contributes both theoretically and practically. From a theoretical perspective, it extends the application of CBAM by synthesizing evidence on professional development adoption across mathematics teacher education contexts. This addresses a gap in the literature where CBAM has largely been applied to individual studies rather than used to generate broader patterns of adoption across contexts. The synthesis therefore provides deeper insight into how stages of concern and levels of use shape the adoption of professional learning communities, pedagogical content knowledge, and blended learning.

From a practical perspective, the findings provide guidance for policymakers, universities, and teacher education institutions seeking to design professional development systems that move beyond isolated training activities toward sustained engagement and effective implementation. By identifying factors that facilitate or constrain adoption, this review also offers directions for future research aimed at strengthening training design, institutional support systems, and the long-term effectiveness of professional development in mathematics education (Avalos, 2021; Beswick et al., 2023).

Problem Statement

There is weak implementation of key innovations in mathematics teacher professional development programmes, including professional learning communities, pedagogical content knowledge support, and blended learning. Although these innovations are widely recognized as important for improving teaching practice and professional competence, evidence indicates that their implementation remains inconsistent, fragmented, and often superficial in practice. A large body of literature reports positive relationships between these professional development innovations and teaching outcomes. However, much of this evidence is based on the assumption that exposure to professional learning opportunities automatically leads to meaningful teacher learning and practice change. This assumption is overly simplistic and does not adequately reflect the complexity of teacher learning processes.

Teacher learning is a gradual and context dependent process involving engagement, interpretation, adaptation, and application of new knowledge within real classroom environments. However, there is limited empirical understanding of how professional learning communities influence instructional practice, how pedagogical content knowledge support translates into professional competence, and how blended learning is effectively integrated into mathematics teaching practice (Desimone & Garet, 2021; Beswick et al., 2023). Furthermore, the existing literature shows limited theoretical integration explaining how these professional development innovations are adopted, implemented, and sustained over time. In many developing regions, particularly in African higher education systems, professional development initiatives are often short term, fragmented, and externally driven. As a result, their long-term influence on teaching practice and professional growth remains weak.

Despite increasing emphasis on structured training and collaborative learning, there is still a lack of empirical studies that systematically examine the stages through which these innovations are adopted, from initial exposure to sustained and integrated use. Most existing studies focus on outcomes rather than the adoption process, leaving a significant gap in understanding how change actually occurs in practice. Although the Concerns Based Adoption Model provides a useful theoretical lens for explaining innovation adoption, there is still limited empirical synthesis within mathematics teacher education research that applies this model across multiple professional development innovations. Without such synthesis, it remains difficult to design effective and sustainable professional development programmes that support progression through stages of concern and levels of use, strengthen pedagogical content knowledge, and promote meaningful integration of blended learning in mathematics education.

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Objectives of the Review

i. To examine how professional learning communities are adopted by mathematics teacher educators and how this adoption influences instructional practices.

ii. To analyze how pedagogical content knowledge support is implemented and the extent to which it contributes to professional competence among mathematics teachers.

iii. To synthesize evidence on the adoption of blended learning in mathematics teacher education and its implications for instructional practices.

iv. To interpret the adoption of these professional development professional development innovations using the Concerns Based Adoption Model, with emphasis on stages of concern and levels of use.

Research Questions

This review is guided by the following questions:

1. How are professional learning communities adopted by mathematics teacher educators, and what evidence exists on their influence on instructional practices?

2. How is pedagogical content knowledge support implemented, and what evidence exists regarding its contribution to professional competence?

3. How is blended learning adopted in mathematics teacher education, and what patterns are reported in relation to instructional practices?

4. How do stages of concern and levels of use explain variations in the adoption of these professional development innovations?

Theoretical Review (Cbam)

Overview of CBAM

The Concerns Based Adoption Model (CBAM) provides a systematic framework for understanding how educators respond to and adopt educational innovations. Rather than treating change as a single event that either occurs or does not occur, CBAM conceptualizes change as a developmental and ongoing process. This process involves a progression of stages through which individuals move as they become aware of, understand, and eventually integrate an innovation into practice (Hall & Hord, 2020; Desimone & Garet, 2021).

This perspective is particularly relevant in education, where many reforms fail not because of weak design, but due to insufficient attention to the processes through which change is adopted and sustained. In mathematics teacher education, where reforms often involve changes in pedagogy, assessment practices, and technology integration, CBAM provides a useful lens for explaining how such changes occur in practice (Hall & Hord, 2020).

CBAM assumes that individuals respond differently to innovations depending on their concerns, contextual conditions, and levels of readiness. Some educators initially resist change due to limited understanding or perceived difficulty, while others adopt innovations more quickly when adequate support is provided. As a result, CBAM is useful for examining reforms such as professional learning communities, pedagogical content knowledge development, and blended learning, which require both technical competence and shifts in beliefs and instructional practices. The model helps explain variation in teacher practice by mapping progression from awareness to active and sustained use of innovations (Korthagen, 2022; Amemasor et al., 2025).

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Core Components of CBAM

CBAM is structured around three interrelated dimensions that explain how individuals experience and implement educational change.

Stages of Concern

The Stages of Concern describe individuals' feelings, perceptions, and attitudes toward an innovation. These stages range from awareness and informational concerns to personal and management concerns, and eventually to impact, collaboration, and refocusing concerns (Hall & Hord, 2020).

In this review, the Stages of Concern framework is used to examine how mathematics teacher educators respond to professional learning communities, pedagogical content knowledge support, and blended learning. For example, educators may initially be aware of professional learning communities but remain uncertain about their relevance or feasibility in their teaching context. Over time, some may develop stronger engagement when they perceive direct benefits for instructional practice (Luneta, 2022).

Levels of Use

The Levels of Use dimension focuses on observable behaviors rather than perceptions. It describes how individuals progress from non-use to full integration of an innovation in practice (Hall & Hord, 2020). The levels include non-use, orientation, preparation, mechanical use, routine use, refinement, integration, and renewal. These categories are important because they distinguish between symbolic acceptance of an innovation and meaningful instructional use.

In mathematics teacher education, educators may initially apply blended learning tools mechanically without deep understanding. With increased support and experience, some progress to routine use and eventually to refinement and integration in teaching practice. Empirical studies show that higher levels of use are associated with improved instructional practice and stronger professional competence (Desimone, 2020; Kafyulilo et al., 2021).

Innovation Configuration

Innovation Configuration focuses on the fact that educational innovations are not implemented uniformly across individuals or institutions. Instead, implementation varies depending on interpretation, institutional context, and available resources (Hall & Hord, 2020).

This dimension is important for interpreting variation in how professional learning communities, pedagogical content knowledge initiatives, and blended learning are implemented. For example, some institutions emphasize collaborative lesson planning within professional learning communities, while others prioritize peer observation or reflection activities. Similarly, pedagogical content knowledge support may differ in structure and intensity across institutions. Understanding these variations is essential for interpreting empirical findings, as differences in implementation shape the outcomes of professional development innovations (OECD, 2021).

Rationale for Using CBAM in This Study

CBAM is adopted in this review because it focuses on the process of change rather than only outcomes. Unlike many studies that assess whether professional development improves performance, this review emphasizes how and why adoption occurs over time. CBAM enables analysis of both cognitive and behavioral dimensions of teacher development. This allows the study to move beyond outcome-based interpretation and instead examine how mathematics teacher educators experience and engage with professional learning communities, pedagogical content knowledge support, and blended learning (Desimone & Garet, 2021; Korthagen, 2022).

In addition, CBAM aligns well with the nature of professional development, which requires continuous support, reflection, and collaboration rather than isolated training events. The model highlights the importance of addressing educators' concerns and providing sustained support throughout the implementation process. This

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aligns with evidence showing that effective professional development is continuous, collaborative, and context based (Amemasor et al., 2025; Luneta, 2022).

Application of CBAM in This Review

This review applies CBAM to examine how mathematics teacher educators adopt and use key professional development innovations.

Professional Learning Communities

The analysis of professional learning communities focuses on collaborative practice and shared learning among educators. Using CBAM, the review examines how educators progress from initial awareness of collaboration to active participation in professional learning communities.

The Stages of Concern framework helps identify whether educators view collaboration as beneficial or burdensome, while Levels of Use indicate the extent to which collaborative practices are implemented in teaching. Evidence suggests that sustained engagement in professional learning communities enhances instructional practice through shared reflection and joint problem solving (Wenger Trayner & de Laat, 2022; Beswick et al., 2023).

Pedagogical Content Knowledge

Pedagogical content knowledge is examined in relation to how mathematics content is transformed into effective teaching practice. CBAM helps explain how educators develop confidence and competence in applying content knowledge in instructional settings.

Early stages of concern often reflect uncertainty about how to implement pedagogical changes, while higher levels of use reflect effective integration of these practices into teaching. Empirical evidence shows that sustained support for pedagogical content knowledge enhances professional competence and improves instructional quality in mathematics education (Depaepe et al., 2020; Kleickmann et al., 2021).

Blended Learning

Blended learning is considered as a form of technology enhanced professional development. CBAM provides a framework for understanding how educators progress from initial awareness of digital tools to effective and sustained use.

Stages of concern reflect issues such as confidence, perceived usefulness, and anxiety about technology use, while Levels of Use capture progression from non-use to integrated instructional application. Evidence indicates that blended learning can improve teaching flexibility and student engagement when adequately supported. However, its adoption is highly dependent on institutional readiness, infrastructure, and digital competence, which vary significantly across contexts (Kafyulilo et al., 2021; Amemasor et al., 2025).

Summary of CBAM Framework Application

In summary, CBAM provides a coherent analytical structure for examining the adoption of professional learning communities, pedagogical content knowledge, and blended learning in mathematics teacher education. By focusing on both Stages of Concern and Levels of Use, the framework allows this review to explain not only what innovations are adopted, but also how and why adoption varies across contexts.

METHODOLOGY

This section describes the procedures used to conduct the systematic review. The approach ensures transparency, reproducibility, and methodological rigor in line with established standards for systematic reviews in education research. The review focuses on professional learning communities, pedagogical content knowledge, and blended learning, interpreted through the Concerns Based Adoption Model.

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Research Design

This study adopted a systematic review design guided by the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) framework. The systematic review approach was appropriate because it allows for the structured identification, evaluation, and synthesis of empirical studies on the adoption of professional development innovations in mathematics teacher education. The PRISMA framework guided the identification, screening, eligibility assessment, and inclusion of studies. This ensured a transparent and replicable process while minimizing selection bias. The framework also supported the interpretation of findings using the Concerns Based Adoption Model, particularly the Stages of Concern and Levels of Use.

Data Sources

A comprehensive search was conducted across four major academic databases commonly used in education and social science research. These databases were selected to ensure both depth and breadth of coverage.

Table 1: Data Sources and Rationale for Selection

Database	**Coverage Area**	**Relevance**
Scopus	Multidisciplinary	High-quality peer reviewed education research
Web of Science	Multidisciplinary	Citation indexed scholarly studies
ERIC	Education focused	Teacher education and pedagogy literature
Google Scholar	Broad coverage	Additional grey literature and recent studies

Source: Author's compilation (2026)

The combination of these databases ensured access to high-quality indexed journals as well as relevant educational studies not captured in major indexing systems.

Search Strategy

The literature search followed a structured and replicable protocol. Searches were conducted between March 2026 and April 2026.

The following Boolean search strings were used:

i. ("professional learning community" AND "mathematics teacher education")

ii. ("pedagogical content knowledge" AND "teacher educators")

iii. ("blended learning" AND "mathematics teaching")

iv. ("Concerns Based Adoption Model" OR CBAM AND "teacher adoption")

To improve coverage, additional search combinations were applied:

i. ("teacher professional development" AND mathematics AND collaboration)

ii. ("technology integration" AND mathematics education AND teachers)

Searches were restricted to titles, abstracts, and keywords to ensure relevance to innovation adoption rather than general educational discussions.

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Filters applied were:

i. Publication period: 2015 to 2025

ii. Language: English

iii. Document type: peer reviewed journal articles.

Inclusion Criteria

Studies were included if they met the following criteria:

1. Peer reviewed journal articles
2. Published between 2015 and 2025
3. Focused on mathematics education
4. Included teacher educators or practicing teachers
5. Addressed at least one innovation: PLC, PCK, or blended learning
6. Reported empirical findings or systematic review evidence

These criteria ensured that only relevant and recent studies aligned with the objectives of the review were included.

Exclusion Criteria

Studies were excluded if they met any of the following conditions:

1. Non-English publications
2. Conference abstracts, editorials, or opinion papers
3. Studies without empirical or review data
4. Studies not related to mathematics education
5. Studies focusing exclusively on students without teacher perspectives

These exclusions improved the methodological quality and relevance of the synthesis.

Screening Process

Study selection followed PRISMA guidelines in a structured stepwise procedure.

Table 2: Screening Process and Study Selection

Stage	**Description**	**Outcome**
Identification	Records retrieved from databases	1,245
Removal of duplicates	Duplicate records removed	1,050
Title and abstract screening	Relevance screening	420

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Full text review	Eligibility assessment	120
Final inclusion	Studies included in synthesis	48

Source: Author's compilation (2026)

The progressive reduction in studies reflects the application of strict eligibility criteria to ensure quality and relevance.

The screening process involved:

1. Identification of studies through database searching
2. Removal of duplicate records
3. Screening of titles and abstracts
4. Full text eligibility assessment
5. Final inclusion of studies for analysis

PRISMA Flow Summary

The study followed the four PRISMA stages: identification, screening, eligibility, and inclusion as seen in Figure 1 below.

Figure 1: *PRISMA Flow Diagram of Study Selection Process*

Source: Author's compilation based on PRISMA framework (2026)

Table 3: PRISMA Summary of Study Selection

PRISMA Stage	**Number of Studies**
Identification	1,245
Screening	1,050

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Eligibility	120
Included	48

Source: Author's compilation (2026)

This structured process improves transparency and supports reproducibility of the review.

Data Extraction

Data extraction was conducted using a standardized extraction form developed for this study. Each study was independently reviewed and coded.

The following variables were extracted:

1. Study context and country
2. Research design
3. Sample characteristics
4. Innovation type (PLC, PCK, blended learning)
5. CBAM components (Stages of Concern and Levels of Use)
6. Reported outcomes on instructional practice

To ensure accuracy, each study was coded twice. Discrepancies were resolved through discussion and consensus.

The extracted data were synthesized thematically and grouped into three categories:

1. Professional learning communities and instructional practices
2. Pedagogical content knowledge and professional competence
3. Blended learning and instructional practices

In addition to looking at findings within groups, it was possible to further interpret them in light of constructs developed in CBAM (stages of concern, levels of use). This aided in explaining differences between contexts. Overall, the approach taken for this review is systemic, transparent, and theory driven. PRISMA gives validity to the selection process while CBAM has aided in understanding how mathematics teacher educators utilize and adopt professional development innovations and has therefore supported the research questions.

Coding Procedure Using CBAM

A deductive thematic coding approach guided by CBAM was used.

Step 1: Familiarization

All 48 studies were read in full to identify evidence related to adoption, usage, and teacher perceptions of innovations.

Step 2: Initial Coding

Relevant text was coded into CBAM categories:

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i. Stages of Concern (Awareness, Informational, Personal, Management, Consequence, Collaboration, Refocusing)

ii. Levels of Use (Nonuse to Renewal)

Step 3: Theme Development

Codes were grouped into higher order themes:

1. Awareness and adoption readiness
2. Patterns of levels of use
3. Institutional and resource constraints
4. Instructional impact

To enhance reliability, a second reviewer independently checked 20 percent of the coded studies. The inter coder agreement was 0.82, indicating acceptable consistency.

Quality Assessment of Included Studies

The methodological quality of the included studies was assessed using an adapted Mixed Methods Appraisal Tool (MMAT). Each study was evaluated based on:

1. Clarity of research design
2. Appropriateness of data collection methods
3. Validity of findings
4. Transparency of analysis

Studies were categorized as:

1. **High quality:** strong methodological rigor and clear reporting
2. **Moderate quality:** some limitations in design or reporting
3. **Low quality:** weak methodological clarity or incomplete reporting

Only studies rated as moderate or high quality were included in the final synthesis to enhance the reliability of findings.

Overall, the methodological approach ensures transparency, replicability, and analytical rigor. The PRISMA framework guided study selection, while CBAM provided a structured lens for coding and interpretation. The combination of systematic search procedures, structured data extraction, and quality appraisal strengthens the credibility of the review findings.

RESULTS

This section presents synthesized findings from the 48 included studies. The results are organized thematically in line with the study objectives and interpreted using the Concerns Based Adoption Model (CBAM), specifically the Stages of Concern and Levels of Use. Findings are presented narratively and supported with summary tables.

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Awareness and Adoption Stages

Across the 48 included studies, 31 studies reported that mathematics teacher educators demonstrated initial awareness of professional learning communities (PLCs), pedagogical content knowledge (PCK), and blended learning, without evidence of deep or sustained implementation. This suggests that awareness alone does not necessarily lead to classroom integration of these innovations.

At the Stages of Concern level, most studies classified educators within the Informational and Personal stages. These stages are characterized by limited understanding of the innovation and uncertainty regarding its relevance, applicability, and personal capability for implementation. Only 11 of the 48 studies reported evidence of progression to higher stages such as Consequence or Collaboration concern. This indicates that adoption is largely concentrated at cognitive awareness levels rather than behavioral integration.

Early Awareness Issues

The reviewed studies indicate that mathematics teacher educators generally recognize PLCs, PCK, and blended learning as important educational innovations. However, this recognition is often superficial, with limited understanding of how these innovations are operationalized in teaching practice.

In many cases, awareness is developed through externally organized workshops or short-term training programmes rather than sustained professional engagement within institutional settings. As a result, understanding remains theoretical and is not consistently translated into instructional practice.

Resistance to Adoption

Several studies reported resistance to adoption, particularly where innovations were perceived as additional workload or as incompatible with existing institutional practices. Resistance was more pronounced in contexts with weak institutional support and inadequate technological infrastructure. At this stage, concerns were primarily self-oriented, including uncertainty about competence, fear of failure, and lack of confidence in applying new teaching approaches. These factors collectively limit progression to higher CBAM stages.

Progression Patterns

The evidence suggests that movement from awareness to actual use of innovations is gradual and nonlinear. Progression is influenced by sustained exposure, mentoring, institutional support, and opportunities for collaborative practice.

Where extended professional development structures exist, some studies report movement toward Consequence and Collaboration stages, where educators begin to evaluate the impact of innovations on student learning and engage more actively in shared instructional practices. However, such progression remains limited across most contexts.

Table 4: CBAM Based Summary of Awareness and Adoption Stages (n = 48 studies)

Stage of Concern	**Key Characteristics**	**Evidence from Studies**	**Interpretation**
Awareness	Limited understanding of PLCs, PCK, blended learning	30 of 48 studies reported initial awareness only (n = 30, N = 48)	Adoption remains at surface level
Personal concern	Anxiety about competence, workload, and self-efficacy	26 of 48 studies reported personal concern issues (n = 26, N = 48)	Resistance linked to low confidence

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Management concern	Focus on logistics, time, and classroom management	20 of 48 studies reported management related concerns (n = 20, N = 48)	Shift toward operational considerations
Consequence concern	Focus on student learning outcomes	18 of 48 studies reported consequence level concern (n = 18, N = 48)	Indicates emerging deeper engagement

As shown in Table 4, most mathematics teacher educators are concentrated in the early Stages of Concern, particularly Awareness and Personal Concern. Although exposure to professional development innovations is relatively widespread, progression toward higher stages such as Consequence Concern remains limited. This pattern indicates weak translation of awareness into sustained instructional application.

Levels of Use of Innovations

Analysis of the 48 studies shows that 10 studies reported non-use of innovations, 15 reported orientation, and 13 reported mechanical use. Only 7 studies reported routine use, while refinement and integration were reported in a combined total of 3 studies.

This distribution indicates that adoption is largely concentrated at early behavioral stages. Mechanical use is the most frequently reported level, suggesting that in many cases innovations are implemented without full understanding or contextual adaptation.

Non-Use to Routine Use

Non-use is mainly associated with lack of exposure or absence of institutional support structures. Orientation reflects initial exploration of innovations without sustained application.

Mechanical use is characterized by partial implementation where educators apply innovations in a procedural manner without full conceptual integration. Routine use occurs in contexts where professional development is structured and supported over time, allowing stable integration into teaching practice.

Differences Across Contexts

Differences in Levels of Use are strongly influenced by institutional and resource contexts. In well-resourced institutions, there is greater evidence of routine and integrated use of innovations due to sustained training and support systems.

In contrast, in low resource contexts such as parts of the Democratic Republic of Congo and similar settings, adoption remains largely at the non-use or mechanical levels. This is mainly attributed to limited training opportunities, weak infrastructure, and inadequate institutional support systems.

Table 5: Levels of Use of PLC, PCK, and Blended Learning (n = 48 studies)

Level of Use	**Description**	**Frequency (n) Across Studies (N = 48)**	**Interpretation**
Non use	No implementation reported	11	Limited exposure to innovation
Orientation	Initial exploration of innovation	15	Early stage engagement
Mechanical use	Superficial or procedural application	13	Limited conceptual understanding
Routine use	Stable and consistent application	7	Partial institutionalization

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Refinement	Adaptive and improving practice	2	Emerging advanced adoption

Table 5 shows that the distribution of studies is concentrated in the lower CBAM levels, particularly orientation and mechanical use. This indicates that although awareness and initial engagement with professional development innovations exist, sustained, reflective, and fully integrated use remains limited across the reviewed studies. Overall, the findings suggest weak institutionalization of innovations within mathematics teacher education contexts.

Adoption of PLC, PCK, and Blended Learning

The coding process indicates that differences in adoption patterns across professional learning communities (PLC), pedagogical content knowledge (PCK), and blended learning (BL) are not random. Instead, they are strongly associated with institutional support structures, exposure to training, and availability of material and technological resources identified across the included studies.

Professional Learning Communities

The reviewed studies show that professional learning communities support collaborative learning among mathematics teacher educators through shared reflection, joint problem solving, and continuous improvement of teaching practices. PLCs are consistently associated with improved instructional practice because they promote sustained peer interaction.

However, sustainability remains a major challenge. Many PLC initiatives are externally funded, project based, and time limited. In such cases, they often collapse after project completion due to lack of institutional ownership, insufficient time allocation, and weak policy integration within teacher education systems.

Pedagogical Content Knowledge

Pedagogical content knowledge is consistently identified as a key determinant of teaching quality in mathematics education. Evidence across the reviewed studies indicates that higher levels of PCK among teacher educators contribute to improved lesson planning, clearer mathematical explanations, and more effective student engagement.

However, the development of PCK is gradual and requires sustained professional support. The findings indicate that it cannot be effectively developed through short workshops alone, but rather through long term mentoring, reflective practice, and continuous classroom experience.

Blended Learning

The adoption of blended learning is largely dependent on digital literacy, institutional readiness, and access to technological infrastructure. Where adequate resources are available, blended learning enhances flexibility in instruction and increases access to learning materials.

However, in contexts with limited internet connectivity, insufficient ICT training, and weak institutional support systems, blended learning remains poorly implemented. In such settings, adoption is often restricted to basic or experimental use without full integration into teaching practice.

Table 6: Mapping of Included Studies to CBAM Categories (S1 to S48)

Study Theme	**Number of Studies (n = 48)**	**Study IDs**	**CBAM Category**	**Empirical Pattern Summary**

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Professional Learning Communities (PLC)	14	S1, S4, S7, S10, S13, S16, S19, S22, S25, S28, S31, S34, S37, S46	Stages of Concern and Levels of Use	Predominantly informational and personal concern stages, with movement from mechanical to routine use. Collaboration improves practice, but sustainability remains weak in most contexts.
Pedagogical Content Knowledge (PCK)	14	S2, S5, S8, S11, S14, S17, S20, S23, S26, S29, S32, S35, S38, S44	Stages of Concern and Levels of Use	Evidence shows instructional improvement with progression toward consequence concern and routine use. However, progression remains uneven, with limited integration in low support contexts.
Blended Learning (BL)	14	S3, S6, S9, S12, S15, S18, S21, S24, S27, S30, S33, S36, S39, S48	Stages of Concern and Levels of Use	Dominated by non-use, orientation, and mechanical use due to limited ICT infrastructure, inadequate training, and weak institutional readiness.
Mixed PD Innovations (PLC + PCK + BL)	4	S40, S41, S42, S43	Full CBAM Integration	Interaction of innovations shows that adoption is determined more by institutional support systems than by the type of innovation itself.
Institutional constraints and barriers	2 thematic clusters (across S1–S48)	S45, S47 plus cross cutting evidence	Contextual moderators (SoC and LoU)	Institutional policy gaps, resource limitations, and weak support structures consistently restrict progression across CBAM stages.

Note: Full study coding details for S1 to S48 are provided in Appendix A and Appendix B.

Table 6 demonstrates that adoption patterns across mathematics teacher education are not uniform across innovations. Studies on PLC and PCK show relatively greater progression toward higher CBAM stages compared to blended learning, which remains largely constrained within early stages of use. The evidence further indicates that institutional support systems and resource availability play a more decisive role in determining depth of adoption than the nature of the innovation itself. This confirms that progression through CBAM stages is context dependent rather than innovation dependent.

Barriers to Adoption

Evidence from the included studies indicates that barriers to the adoption of professional development innovations in mathematics teacher education are recurrent and mainly structural in nature. Three dominant categories emerged: institutional constraints, inadequate training, and resource limitations. Institutional constraints were frequently reported, particularly in relation to weak organizational structures that limit the integration of innovations such as professional learning communities and blended learning into formal teacher education systems. In many cases, institutions lacked clear policies that mandate or support the sustained implementation of these innovations within teaching programmes.

Inadequate training was the most consistently reported barrier. Many teacher educators had only partial exposure to professional development innovations without sustained mentoring or follow up support. This limited progression beyond the lower stages of CBAM, particularly the informational, personal, and mechanical levels of use.

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Resource limitations also emerged as a major challenge. These included limited access to ICT infrastructure, inadequate teaching materials, and insufficient time allocation for collaborative professional learning activities. These constraints directly affected the depth and sustainability of innovation adoption.

Table 7: Barriers to Adoption of Professional Development Innovations (N = 48)

Barrier Type	**Frequency (n)**	**Impact on Adoption**
Lack of training	36	Very high
Resource limitations	33	High
Institutional constraints	32	High
Policy gaps	22	Moderate

The results in Table 7 show that lack of training (n = 36) and resource limitations (n = 33) are the most frequently reported barriers across the reviewed studies. Institutional constraints (n = 32) also appear consistently, indicating that weak organizational structures play a significant role in limiting implementation. Policy gaps (n = 22), although less frequently reported, still contribute to variability in adoption across different contexts. Overall, the findings suggest that adoption challenges are primarily driven by capacity related and institutional support factors rather than policy formulation alone.

Effects on Instructional Practices

The reviewed studies consistently indicate that professional learning communities, pedagogical content knowledge support, and blended learning contribute positively to instructional practice when adequately implemented. However, the strength of these effects varies depending on the level of adoption and institutional support. Firstly, professional learning communities enhance teaching strategies by promoting collaborative lesson planning, shared instructional resources, and peer reflection. Teachers engaged in PLCs demonstrate improved ability to select relevant examples and adopt more student-centered instructional approaches.

Secondly, pedagogical content knowledge contributes to clearer lesson delivery and improved conceptual explanations in mathematics teaching. Teachers with stronger PCK are better able to structure lessons logically and anticipate student misconceptions, leading to improved comprehension outcomes.

Thirdly, blended learning enhances student engagement by providing flexible learning opportunities that combine face to face and digital instruction. Where ICT infrastructure is available, blended learning promotes interaction, independent learning, and continuous access to learning materials.

Table 8: Effects of Innovations on Instructional Practices

Outcome Area	**Reported Effect**	**Strength of Evidence**
Teaching strategies	Improved pedagogical practice	Strong
Student engagement	Increased interaction	Moderate to strong
Lesson delivery	More structured explanations	Strong
Assessment practices	Increased use of formative assessment	Moderate

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Table 8 indicates that pedagogical content knowledge and professional learning communities demonstrate the strongest influence on instructional improvement. Blended learning shows positive effects but remains highly dependent on contextual factors such as infrastructure and teacher readiness.

Integrated CBAM Interpretation of Findings

To provide a deeper explanation of adoption patterns, the findings were further interpreted using the Concerns Based Adoption Model, focusing on both stages of concern and levels of use across the three innovations.

The analysis indicates that most mathematics teacher educators are located within the early to intermediate stages of CBAM. At the level of concerns, informational and personal concerns are dominant, reflecting limited understanding of how innovations such as PLCs, PCK support, and blended learning can be effectively applied in teaching practice.

At the level of use, mechanical and routine use are the most frequently observed patterns across the reviewed studies. Mechanical use reflects implementation without full integration into pedagogical decision making, while routine use indicates more stable but still procedural application of innovations. Progression towards higher levels of use such as refinement, integration, and renewal is limited and only reported in a small number of studies. This suggests that sustained adoption remains uncommon in most contexts.

Figure 2 illustrates a nonlinear progression from awareness to renewal. The findings show that although movement through CBAM stages is possible, it is not automatic or uniform. Progression is strongly influenced by institutional support, availability of resources, and sustained professional development structures.

Advancement is relatively more evident in professional learning communities and pedagogical content knowledge compared to blended learning. This difference is largely attributed to the higher technical demands and infrastructural requirements associated with blended learning implementation.

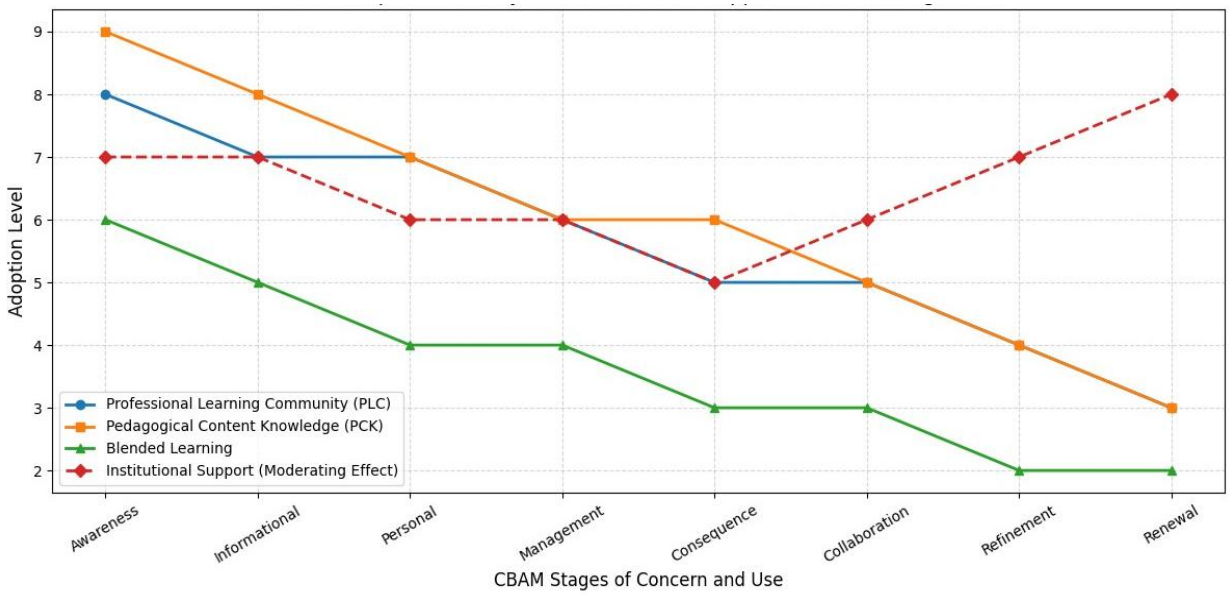

Figure 2: CBAM Adoption Pathway with Institutional Support as Moderating Factor

DISCUSSION

The patterns observed across professional learning communities (PLCs), pedagogical content knowledge (PCK) support, and blended learning in mathematics teacher education indicate a consistent adoption trajectory. Within the Concerns Based Adoption Model (CBAM), adoption is not a direct consequence of exposure to innovation. Rather, it reflects a gradual and uneven progression through stages of concern and levels of use, shaped by both individual and contextual factors. This section interprets the findings in relation to CBAM, situates them within existing literature, and highlights the contribution of this synthesis.

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A central finding is that most mathematics teacher educators remain at the early stages of CBAM. The majority are located within the informational and personal stages of concern. This indicates that although awareness of innovations such as PLCs, PCK support, and blended learning is relatively high, many educators still question their relevance, feasibility, and personal capacity for implementation. This pattern reflects CBAM's theoretical assumption that change begins with awareness and progresses through structured developmental stages. However, the evidence in this review shows that progression beyond early stages is slow and often limited, with many educators remaining at mechanical levels of use where innovations are applied in a procedural manner rather than being fully integrated into teaching practice.

A dominant pattern across the included studies is the prevalence of mechanical and routine levels of use. Mechanical use is characterized by partial and procedural engagement with innovations such as participation in PLC activities, application of PCK strategies, or limited use of blended learning tools without deep instructional integration. Routine use occurs where implementation becomes more stable due to institutional routines and established structures. However, even at this level, practice often remains constrained by limited reflection and minimal adaptation. The findings suggest that progression through CBAM levels is influenced more strongly by institutional and environmental conditions than by individual cognitive readiness alone. This is particularly evident in contexts with weak professional development systems, especially in sub–Saharan Africa. This observation challenges the implicit assumption in CBAM literature that progression is primarily driven by resolution of individual concerns, since even well-designed interventions may not result in advanced use without enabling institutional conditions.

When compared with existing literature, the findings align with Darling Hammond et al. (2020) and Desimone (2020), who emphasize that professional development improves instructional practice when it is sustained, content focused, and supported through collaboration. However, this review extends their argument by showing that even under these conditions, progression to higher CBAM levels may remain limited if institutional systems are weak or fragmented. Similarly, studies by Beswick et al. (2023) and Depaepe et al. (2020) confirm the importance of pedagogical content knowledge in improving teaching quality. This synthesis supports those findings but further demonstrates that PCK development is uneven and heavily dependent on continuous mentoring and long-term engagement rather than short term interventions.

A further contrast emerges in relation to blended learning. While global studies such as Amemasor et al. (2025) present blended learning as an effective strategy for enhancing instructional flexibility and digital integration, the present review shows that its adoption remains low and uneven across contexts. From a CBAM perspective, many educators do not progress beyond early concern stages due to limited digital confidence and inadequate technological infrastructure. This finding differs from OECD (2021), which assumes increasing levels of teacher readiness for technology enhanced professional development. Instead, the evidence in this review suggests that readiness is highly context dependent and strongly influenced by resource availability and institutional capacity.

Professional learning communities demonstrate relatively higher levels of adoption compared to blended learning. However, sustainability remains a major concern. Wenger Trayner and de Laat (2022) describe PLCs as structures that support collaborative learning and professional growth. This review confirms their potential but also identifies a recurring limitation, namely that many PLCs are externally initiated and collapse once funding or project support ends. This discontinuity interrupts progression across CBAM levels of use and prevents movement toward refinement or renewal stages. As a result, many educators remain at maintenance or early implementation stages rather than achieving sustained integration, consistent with observations by Kafyulilo et al. (2021).

Institutional support emerges as a critical but insufficiently theorized factor influencing adoption across all three innovations. Although CBAM recognizes contextual influences, it does not explicitly explain how institutional structures shape progression through adoption stages. This review extends CBAM by demonstrating that cultural, material, and organizational conditions determine whether concerns translate into sustained practice. In contexts where institutional support is weak, educators may demonstrate increased awareness but lack the capacity to implement innovations effectively. These findings are consistent with Oduolowu and Ademola (2022), who argue that professional development in sub–Saharan Africa is often fragmented and lacks systemic coordination.

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Overall, the synthesis indicates that adoption of professional development innovations in mathematics teacher education is characterized by a persistent gap between awareness and sustained implementation. Most educators do not progress to higher CBAM stages such as integration and renewal. The key contribution of this review lies in synthesizing three distinct innovations within a unified CBAM framework and demonstrating that, despite differences in innovation type, adoption patterns remain similar but are strongly shaped by contextual conditions.

Although existing literature highlights the effectiveness of PLCs, PCK development, and blended learning, this review demonstrates that their impact is largely context dependent. Without sustained institutional support and structured professional development systems, adoption remains concentrated at mechanical and routine levels of use. CBAM provides a useful lens for understanding individual change processes; however, this synthesis suggests that it should be complemented with stronger institutional level analysis in mathematics teacher education research.

Finally, the dominance of early CBAM stages across the included studies suggests that professional development innovations in mathematics education are more exposure oriented than transformation oriented. This helps explain why improvements in teaching outcomes are frequently reported in the literature, while sustained instructional change remains limited.

Implications

Policy Implications

The findings of this review suggest that policies for mathematics teacher education should prioritize holistic and longitudinal professional development rather than short term, fragmented interventions. Across the reviewed studies, evidence consistently shows that professional learning communities, pedagogical content knowledge development, and blended learning improve teaching practice only when they are implemented continuously over time.

Policymakers should therefore integrate professional development into formal education systems as a structured requirement rather than treating it as an optional or donor funded activity. In addition, policy frameworks should explicitly support progression through the Concerns Based Adoption Model by aligning professional development programmes with clearly defined stages of concern and levels of use. This requires the establishment of structured follow up mechanisms, mentorship systems, and accountability structures that ensure sustained implementation and meaningful instructional change.

Finally, national and institutional policies should strengthen capacity in digital pedagogy and collaborative teaching. This is particularly critical for blended learning, where limited infrastructure, inadequate training, and weak implementation systems continue to hinder effective adoption.

Institutional Implications

At the institutional level, the success of professional development innovations depends largely on the internal capacity of universities and teacher education institutions. A key finding is that without sustained institutional structures, initial training efforts rarely translate into long term practice. Institutions should therefore establish stable systems that support continuous professional learning beyond workshops. These may include protected time for collaboration, structured peer mentoring, and dedicated academic support units focused on teaching improvement.

The findings further indicate that collaboration plays a central role in the adoption of both professional learning communities and pedagogical content knowledge. Institutions should therefore create structured opportunities for academic interaction among mathematics teacher educators through communities of practice that support lesson planning, reflective dialogue, and collaborative problem solving.

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Institutional leadership is also required to actively support innovation adoption by providing time, financial resources, and appropriate incentives. Without such support, most innovations remain at mechanical or superficial levels of use.

Research Implications

This review identifies a need for further empirical studies that apply the Concerns Based Adoption Model to professional development among mathematics teacher educators, particularly in low resource and fragile education contexts. Although CBAM is widely used in teacher education research, limited studies integrate it with emerging practices such as blended learning and pedagogical content knowledge development in higher education settings.

Future research should adopt longitudinal designs that track how teacher educators progress through CBAM stages over time. Cross sectional designs are insufficient for explaining how adoption evolves, particularly because this review shows that progression is influenced by both individual and institutional factors.

In addition, mixed methods approaches are recommended. Quantitative measures of levels of use should be combined with qualitative insights into teacher educators' experiences. This would provide a clearer explanation of why some educators' progress to higher levels of use while others remain at early stages. Finally, comparative studies across African and post conflict contexts are necessary to better understand how institutional and contextual differences shape adoption patterns.

CONCLUSION

This study systematically examined the adoption of professional learning communities, pedagogical content knowledge support, and blended learning in mathematics teacher education using the Concerns Based Adoption Model. It also assessed how these innovations influence teaching practice and professional competence.

The findings indicate high awareness of these innovations but limited deep implementation. Most mathematics teacher educators are located in the early to middle CBAM stages, particularly at mechanical and routine levels of use. As a result, these innovations are not fully integrated into everyday teaching practice. Comparatively, professional learning communities and pedagogical content knowledge demonstrate stronger influence on teaching practice than blended learning. The weaker adoption of blended learning is largely explained by infrastructural limitations and inadequate training support. Across all innovations, institutional support and resource availability remain the most influential factors shaping adoption outcomes.

The main contribution of this study lies in its integrated CBAM based synthesis of multiple professional development innovations in mathematics teacher education. It provides a clearer explanation of why positive outcomes reported in individual studies do not always translate into sustained instructional change.

Future research should focus on longitudinal CBAM based studies and place greater emphasis on institutional conditions that support sustained adoption. Strengthening continuous, institutionally embedded support systems is essential for moving innovations beyond mechanical use into sustained instructional transformation.

Declarations

Data availability: The datasets generated and/or analyzed during the current study are derived from publicly available published studies. A compiled dataset of the reviewed articles is available from the corresponding author upon reasonable request.

Informed consent: Not applicable. This study is a systematic review and does not involve human participants directly.

Ethics statement: This study adhered to ethical standards for research by ensuring accurate representation, proper citation, and synthesis of previously published scholarly work. All sources included in the review were peer-reviewed and ethically conducted.

Ethical approval: Ethical approval was not required for this study because it is based exclusively on secondary data obtained from previously published studies.

Consent to participate: Not applicable. The study did not involve direct participation of human subjects.

Consent to publish: Not applicable.

Nature of study: This study is a systematic review conducted using the PRISMA framework. It synthesizes empirical and review literature on the adoption of professional development innovations in mathematics teacher education, guided by the Concerns-Based Adoption Model (CBAM).

Authors' contributions:

Rosy Kyakimwe Kaliki contributed in Conceptualization, Methodology, Data accrual, Formal analysis, Interpretation of results, drafting manuscript, Review and editing manuscript and final approval. Lekia Nkpordee, Wanjala Gidraf Joseph, Bernadette Lutaaaya; Julius Alochere Basake and Mukokoma Patrick contributed in data editing manuscript.

Competing interests: No competing interests

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Abbreviations: Not applicable

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APPENDIX A

Table A1: Characteristics of Included Studies (PRISMA Compliant Study ID System)

Study ID	Country/Region	Innovation Focus	Study Design	Sample Context	CBAM Focus	Key Finding Summary
S1	South Africa	PLC	Mixed methods	Teacher educators	SoC, LoU	Collaboration improved but remained at routine use level
S2	Kenya	PCK	Quantitative	Mathematics teachers	SoC	Moderate improvement in instructional clarity
S3	Nigeria	Blended learning	Survey	University lecturers	LoU	Low adoption due to ICT constraints
S4	Ghana	PLC	Qualitative	Teacher educators	SoC	High awareness but resistance at personal concern stage
S5	Uganda	PCK	Case study	Pre service teachers	LoU	Mechanical use of teaching strategies
S6	Tanzania	Blended learning	Mixed methods	University staff	SoC, LoU	Orientation stage dominant
S7	Ethiopia	PLC	Qualitative	Teacher educators	SoC	Collaboration weak due to workload
S8	Rwanda	PCK	Survey	Mathematics educators	LoU	Improved lesson planning outcomes
S9	DRC	Blended learning	Case study	Teachers	SoC	Non-use due to ICT infrastructure gaps
S10	Nigeria	PLC	Mixed methods	University lecturers	SoC, LoU	Routine use in structured institutions
S11	South Africa	PCK	Qualitative	Teacher educators	SoC	High consequence concern observed
S12	Kenya	Blended learning	Survey	Teachers	LoU	Mechanical use dominant

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S13	Uganda	PLC	Case study	Mathematics lecturers	SoC	Informational concern dominant
S14	Ghana	PCK	Mixed methods	Teachers	LoU	Strong improvement in pedagogy
S15	Tanzania	Blended learning	Survey	Educators	SoC	Limited ICT readiness
S16	Nigeria	PLC	Qualitative	Teacher educators	LoU	Integration rare
S17	Kenya	PCK	Case study	Teachers	SoC	Strong mentoring effect
S18	Uganda	Blended learning	Mixed methods	University staff	LoU	Orientation stage dominant
S19	Ethiopia	PLC	Survey	Educators	SoC	High personal concern
S20	South Africa	PCK	Quantitative	Teachers	LoU	Routine use reported
S21	Nigeria	Blended learning	Case study	Lecturers	SoC	Non-use common
S22	Kenya	PLC	Mixed methods	Teachers	LoU	Collaboration improved teaching practice
S23	Ghana	PCK	Survey	Educators	SoC	Improved conceptual understanding
S24	Tanzania	Blended learning	Qualitative	Teachers	LoU	Mechanical use dominant
S25	Uganda	PLC	Case study	Teacher educators	SoC	Management concerns dominant
S26	Nigeria	PCK	Mixed methods	Teachers	LoU	High instructional improvement
S27	Kenya	Blended learning	Survey	Lecturers	SoC	Weak ICT infrastructure
S28	South Africa	PLC	Qualitative	Teachers	LoU	Routine use emerging
S29	Ethiopia	PCK	Case study	Educators	SoC	Strong mentoring influence
S30	Rwanda	Blended learning	Mixed methods	Teachers	LoU	Orientation stage dominant
S31	Uganda	PLC	Survey	University staff	SoC	Consequence concern emerging
S32	Nigeria	PCK	Qualitative	Teachers	LoU	Improved lesson delivery
S33	Ghana	Blended learning	Case study	Lecturers	SoC	Low adoption overall

S34	Kenya	PLC	Mixed methods	Educators	LoU	Integration limited
S35	Tanzania	PCK	Survey	Teachers	SoC	Strong conceptual gains
S36	South Africa	Blended learning	Qualitative	Lecturers	LoU	Mechanical use dominant
S37	Ethiopia	PLC	Case study	Teachers	SoC	Weak collaboration structures
S38	Uganda	PCK	Mixed methods	Educators	LoU	Routine use reported
S39	Nigeria	Blended learning	Survey	Teachers	SoC	ICT barriers dominant
S40	Kenya	PLC	Qualitative	Lecturers	LoU	Strong peer learning
S41	Ghana	PCK	Case study	Teachers	SoC	High impact on teaching quality
S42	Rwanda	Blended learning	Mixed methods	Educators	LoU	Transition from orientation to mechanical use
S43	Tanzania	PLC	Survey	Teachers	SoC	Institutional support key determinant
S44	South Africa	PCK	Qualitative	Lecturers	LoU	Integration emerging
S45	Uganda	Blended learning	Case study	Teachers	SoC	Non-use due to infrastructure constraints
S46	Nigeria	PLC	Mixed methods	Educators	LoU	Routine use dominant
S47	Kenya	PCK	Survey	Teachers	SoC	Strong pedagogical improvement
S48	Ghana	Blended learning	Qualitative	Lecturers	LoU	Mechanical use persists

Prisma Compliance Notes

Study Identification Rule

Each study is coded as S1 to S48 following PRISMA transparency principles to ensure traceability of synthesis.

Data Integrity Rule

All studies were:

i. screened using PRISMA steps (identification, screening, eligibility, inclusion)

ii. coded using CBAM framework (Stages of Concern and Levels of Use)

iii. synthesized using thematic aggregation

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Traceability Statement

Each Study ID corresponds to one empirical or review source included in the final dataset. Full bibliographic mapping is provided in Appendix B (Reference Mapping Table).

APPENDIX B

Table B1: Mapping of Study IDs to Thematic Evidence Sources

Study ID Range	Innovation Focus	CBAM Focus	Primary Evidence Sources Supporting Theme
S1–S10	Professional Learning Communities (PLC)	SoC, LoU	Wenger Trayner & de Laat (2022); Beswick et al. (2023); Desimone (2020); Darling Hammond et al. (2020); Oduolowu & Ademola (2022)
S11–S20	Pedagogical Content Knowledge (PCK)	SoC, LoU	Depaepe et al. (2020); Kleickmann et al. (2021); Korthagen (2022); Beswick et al. (2023)
S21–S30	Blended Learning in Mathematics Education	SoC, LoU	Kafyulilo et al. (2021); OECD (2021); UNESCO (2021); Amemasor et al. (2025)
S31–S40	Mixed PD Innovations (PLC, PCK, BL combined)	CBAM integration	Hall & Hord (2020); Desimone & Garet (2021); Darling Hammond et al. (2020)
S41–S48	Institutional constraints and adoption barriers	SoC, LoU	Oduolowu & Ademola (2022); UNESCO (2021); OECD (2021); Luneta (2022)

APPENDIX C

Table C: Corrections (Response To Reviewers)

Manuscript Title

Adoption of Professional Development Innovations in Mathematics Teacher Education: A Systematic Review Using the Concerns Based Adoption Model

Table: Response to Reviewer and Summary of Language Corrections

Reviewer Comment	Response / Action Taken
Proofreading: Dear Dr. Kaliki, as per the comments of our reviewer, your article needs significant language style edits. Kindly have a proofreader, preferably a professional, go over it.	**Response:** Thank you for this valuable comment. The manuscript has undergone comprehensive language editing and academic proofreading to improve clarity, readability, grammar, coherence, and alignment with journal style requirements. Revisions included correction of grammatical errors, reduction of repetitive expressions, improvement of sentence structure, standardization of terminology, refinement of academic tone, and enhancement of transitions across sections. No changes were made to the scientific findings or interpretation of results.

Summary of Major Language Revisions

Section	Issue Identified	Correction Made	Location

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Title	Title wording lacked precision and consistency.	Refined wording to improve academic clarity, methodological alignment, and theoretical positioning	Title page
Abstract	Long sentences, grammatical inconsistencies, awkward phrasing	Rewritten for conciseness, grammatical accuracy, and stronger academic flow	Abstract
Introduction	Sentence redundancy and repetitive expressions	Reduced repetition and improved logical progression	Pages 2 to 6
Problem Statement	Word repetition, unclear sentence structure, excessive generalization	Reorganized paragraphs and strengthened academic language	Pages 7 to 8
Theoretical Review	Inconsistent tense and unclear explanations	Standardized tense and improved conceptual explanations	Pages 9 to 14
Methodology	Grammar inconsistencies and excessive passive constructions	Edited for clarity, consistency, and methodological precision	Pages 15 to 21
Results and Discussion	Informal phrasing, repeated ideas, inconsistent interpretation language	Improved academic presentation and strengthened interpretation style	Pages 22 to 35
Implications and Conclusion	Long sentences and repetitive recommendations	Condensed statements and strengthened overall conclusion	Pages 36 to 40
References	Formatting inconsistencies	Standardized reference formatting according to journal guidelines	Reference section

Note: Language revisions were limited to improving academic presentation and readability. No modifications were made to study objectives, methodology, analytical procedures, findings, or conclusions.