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Evolving Teacher Professional Development in the Age of AI: Revisiting PCK, TPACK, and the DECODE Model

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Abstract: Current teacher professional development (TPD) models often face challenges of sustainability, contextual adaptability, and limited integration of emerging technologies. This study introduces the DECODE model, a cyclical, AI-supported professional development (PD) framework designed to enhance teachers' Technological Pedagogical Content Knowledge (TPACK), academic resilience, and instructional competence in post-pandemic contexts. Grounded in TPACK, Pedagogical Content Knowledge (PCK), and self-regulated learning, the DECODE model includes four phases: DEMO, CO-design/teach, feedback, and DEbriefing. AI is integrated to provide adaptive feedback, automate lesson analysis, and scale individualized coaching. Synthesizing five empirical studies conducted across Taiwan, Indonesia, India, and Vietnam, the findings confirm DECODE's positive impact on TPACK development, reflective thinking, and adaptive instruction. Participants reported increased technological confidence, resilience, and engagement. The study highlights DECODE's scalability and potential for AI-enhanced teacher education in diverse cultural contexts, with future directions focusing on embedding DECODE into formal TPD systems and institutional practices.

Keywords: Teacher Professional Development, DECODE Model, TPACK, PCK, AI in Education, Self-Regulated Learning

1. Introduction

The DECODE model addresses the evolving needs of teacher professional development (TPD) in the digital era, particularly in post-pandemic contexts (Whalen, 2020). Grounded in Pedagogical Content Knowledge - PCK (Shulman, 1986), Technological Pedagogical Content Knowledge – TPACK (Mishra & Koehler, 2006), and Self-Regulated Learning (SRL) (Zimmerman, 2002), DECODE responds to the demands for scalable, practice-based, and culturally adaptable frameworks. However, existing TPD models often face limitations in sustainability, contextual adaptability, and the integration of emerging technologies. Many initiatives remain fragmented, overly theoretical, or difficult to scale across cultural contexts. These issues highlight the need for a more dynamic and practice-based model. While AI is often regarded as a trend in education, its relevance to TPD lies in addressing persistent gaps: providing real-time, personalized feedback; automating lesson analysis; and scaling individualized coaching for teachers. Without AI integration, TPD programs risk remaining generic and resource-intensive. It builds on cognitive apprenticeship and expands prior models like MAGDAIRE, streamlining TPD into four iterative phases: DEMO, CO-design/teach, feedback, and DEbriefing. This model is enhanced through the integration of

platforms like CloudClassRoom (CCR), supporting real-time feedback and collaborative lesson design.

2. Methods

This study presents a model-based synthesis of five implementation cases of the DECODE professional development model conducted in Taiwan, Indonesia, India, and Vietnam between 2019 and 2024. These cases were designed to evaluate the model's effectiveness in strengthening teachers' TPACK, SRL, and instructional resilience. Each case has been peer-reviewed and published individually between 2022 and 2024, providing validated empirical evidence for the synthesis presented here.

A mixed-methods approach was employed across the five studies. Quantitative data were primarily collected through validated TPACK and SRL questionnaires adapted from established scales (e.g., Koh et al., 2010), along with lesson plan rubrics. Statistical techniques such as paired-sample t-tests and path analysis were applied in the original studies to measure gains in knowledge integration, self-regulation, and instructional competence. Complementing this, qualitative data were collected through reflective journals and open-ended surveys. These were analyzed thematically using tools such as NVivo, revealing teachers' evolving perceptions of technology-enhanced pedagogy and instructional practices.

All implementations followed the structured DECODE cycle: demonstration, co-design, co-teaching, feedback, and debriefing. In several cases, the CCR platform was integrated to provide AI-enhanced features, including automated feedback analysis, real-time analytics of student responses, personalized teacher dashboards, and intelligent diagnostics to support instructional adjustments.

To capture cross-contextual insights, the synthesis adopted a structured comparative approach, including thematic comparison and tabular cross-case analysis. This allowed the authors to refine the DECODE model iteratively, ensuring its adaptability to diverse educational contexts.

3. Results

The studies consistently showed improvements in TPACK, instructional competence, and teacher resilience. In Taiwan, TPACK scores significantly increased (Cohen's d = 0.84). Indian participants reported gains in academic resilience and teaching competence. Indonesian teachers exhibited improvement across TPACK domains with large effect sizes (d = 0.82). Vietnamese teachers showed gains in TPACK-I, though implementation challenges in inquiry-based elements remained. Common themes included enhanced peer collaboration, confidence in tech integration, and adaptive instructional design. In cases supported by AI tools, teachers particularly highlighted the value of adaptive feedback and real-time analytics in strengthening their instructional competence.

Beyond the quantitative data presented above, the findings also reflect context-specific developments across national settings. For instance, in Taiwan, the notable increase in TPACK scores (Cohen's d = 0.84) not only indicates greater confidence in technology integration but also suggests teachers' growing capacity to independently design and implement digital learning activities. In India, reported improvements in academic resilience and pedagogical competence highlight the role of DECODE in helping teachers sustain motivation, adapt flexibly to challenges, and manage diverse classrooms. Meanwhile, Indonesian teachers demonstrated consistent improvement across all TPACK domains, with a large effect size (d = 0.82). This suggests that the cyclical structure of DECODE, combined with co-design and feedback activities, is particularly well-suited to fostering holistic professional growth. For Vietnamese teachers, the results showed significant gains in TPACK-I, yet challenges remained in applying inquiry-based learning strategies. These difficulties may reflect constraints related to time, resources, and familiarity with

constructivist teaching approaches. This indicates that while DECODE strengthens TPACK-I competencies, its success in fostering inquiry-based practices may require additional scaffolding and localized adaptation.

In addition to these country-specific outcomes, several cross-cutting themes emerged throughout the study. Teachers in all four countries reported enhanced peer collaboration, increased confidence in technology integration, and improved capacity to design adaptive instructional activities. Qualitative reflections further revealed that AI-supported tools (e.g., the CCR dashboard) enabled timely, personalized feedback, reducing reliance on external experts. Moreover, many teachers valued group-based reflective practices as a means of cultivating professional resilience and sustaining long-term motivation. These AI-supported mechanisms also suggest pathways for scaling professional development by reducing dependence on intensive human facilitation.

Taken together, these findings not only affirm the positive impact of DECODE on teachers' professional competencies across diverse contexts but also illuminate the practical challenges that remain in implementation. These issues will be explored in greater depth in the following discussion section.

4. Discussion

The synthesis of five implementation studies demonstrates that the DECODE model, structured around cycles of demonstration, co-design, co-teaching, and feedback, is a promising framework for enhancing teachers' TPACK, instructional competence, and academic resilience across diverse educational contexts. The integration of self-regulated learning strategies further enhanced adaptability and reflective thinking, both of which are essential for teaching in technology-enriched environments. These findings align with prior research emphasizing the importance of structured, collaborative training in developing TPACK and 21st-century teaching skills (Chai et al., 2013; Koh et al., 2010).

Across all implementation sites, participants reported greater confidence, collaboration, and engagement in their teaching practices. In Taiwan, the significant gains in TPACK underscored teachers' increasing ability to independently design technology-rich lessons. In India, improvements in academic resilience highlighted DECODE's role in sustaining teachers' motivation and adaptability under challenging conditions. Indonesian teachers exhibited consistent gains across TPACK domains with large effect sizes, reflecting the suitability of the cyclical DECODE structure in fostering holistic growth. Vietnamese teachers also showed significant improvement in TPACK-I, though challenges persisted in inquiry-based practices due to contextual constraints.

At the same time, the observed gap between self-reported progress and actual instructional performance—particularly regarding inquiry-based pedagogy—echoes findings from Mishra and Koehler (2006) and Tondeur et al. (2012), who noted that teachers often overestimate their ability to implement complex pedagogical strategies. This gap suggests a continued need for scaffolding, guided practice, and formative feedback mechanisms. Importantly, AI-supported tools such as CCR dashboards and adaptive analytics played a critical role in bridging this gap by offering timely, personalized feedback and reducing reliance on external experts.

Furthermore, the model's scalability and integration of AI-enhanced features align with recent calls for equity-driven, sustainable teacher professional development (Philipsen et al., 2019). Beyond immediate outcomes, DECODE demonstrates potential for institutional adoption, where embedding the cycle into existing TPD systems and training teacher-leaders could sustain the model without ongoing research intervention. Such measures would ensure that AI-driven analytics and feedback become integral components of everyday teaching practices, rather than temporary innovations.

Overall, a comparative review of the five DECODE implementations indicates that the model not only advances teachers' technological and pedagogical skills but also addresses the emotional and cognitive demands of modern classrooms. Future research should extend its long-term impact by refining AI-enhanced feedback systems, implementing continuous

performance monitoring, and scaling integration within institutional professional development strategies. In doing so, DECODE can evolve into a sustainable, globally adaptable framework that prepares teachers for the complexities of AI-enriched education.

5. Conclusion

In conclusion, DECODE offers a flexible, replicable model for AI-integrated professional development, extending existing TPD models grounded in TPACK and SRL (Mishra & Koehler, 2006; Zimmerman, 2002). It strengthens TPACK and promotes resilience in post-pandemic teaching. Future directions include deeper AI integration (e.g., adaptive dashboards, video analytics) to support personalized, real-time professional growth. This aligns with broader educational shifts toward intelligent, responsive systems for teacher support in the 21st century. Moving forward, transitioning DECODE into a sustainable model requires embedding it into national TPD policies, fostering institutional partnerships, and training teacher-leaders who can independently facilitate the DECODE cycle. These steps ensure the initiative can move from a research-based implementation to a self-sustaining system.

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