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Digital Pedagogical Competencies among Pre-Service Teachers: A Systematic Review and Meta-Synthesis of Empirical Studies (2018–2024)

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Abstract

The rapid digitalization of education, accelerated by the COVID-19 pandemic, has intensified the need for pre-service teachers to develop robust digital pedagogical competencies. This systematic review synthesizes empirical research published between 2018 and 2024, examining the nature, development, and assessment of digital pedagogical competencies among pre-service teachers globally. Following PRISMA guidelines, 78 peer-reviewed studies were identified from SCOPUS, Web of Science, ERIC, and Education Source databases. The review employs thematic synthesis to analyse theoretical frameworks, competence dimensions, influencing factors, and assessment approaches. Findings reveal that the Technological Pedagogical Content Knowledge (TPACK) and European Framework for the Digital Competence of Educators (DigCompEdu) dominate the conceptual landscape, though significant variations exist in their operationalization. Five major influencing dimensions emerge: training and curriculum design, psychological factors including self-efficacy and attitudes, institutional support systems, ethical and critical digital literacy, and individual characteristics. The COVID-19 pandemic catalysed significant competence development but also exposed disparities in readiness and access. Evidence indicates that while pre-service teachers demonstrate adequate foundational digital skills, gaps persist in pedagogical integration, ethical awareness, and critical evaluation of digital resources. The review identifies methodological limitations in existing research, particularly the predominance of self-reported measures and cross-sectional designs. Recommendations emphasize integrated curriculum approaches, authentic technology-enhanced practicum experiences, and alignment with frameworks like India's National Education Policy 2020 to prepare future teachers for technology-rich classrooms.

Keywords: - Digital pedagogical competencies; Pre-service teachers; TPACK; DigCompEdu; Systematic review; Teacher education

I. INTRODUCTION

The twenty-first century educational landscape demands teachers who can effectively integrate digital technologies into pedagogical practice. Digital pedagogical competence, encompassing the knowledge, skills, and attitudes required to use digital technologies for teaching, learning, and professional development, has emerged as a critical component of teacher preparation (Redecker & Punie, 2017). The imperative for digitally competent educators has intensified following the COVID-19 pandemic, which forced unprecedented transitions to online and hybrid teaching modalities (Howard et al., 2022).

Pre-service teachers occupy a unique position in this transformation. As digital natives entering a profession increasingly dependent on technology, they are expected to possess foundational technological fluency while developing the pedagogical expertise to leverage these tools for enhanced learning outcomes (Tondeur et al., 2017). However, research suggests a persistent gap between technological familiarity and pedagogical application, with many teacher education programmes struggling to adequately prepare candidates for technology-rich classrooms (Schmid et al., 2024).

Multiple theoretical frameworks have emerged to conceptualize teachers' digital competencies. (Mishra & Koehler, 2006) Technological Pedagogical Content Knowledge (TPACK) framework has dominated research, proposing that effective technology integration requires the intersection of technological, pedagogical, and content knowledge. More recently, the European Framework for the Digital Competence of Educators (DigCompEdu) offers a comprehensive structure identifying

22 competencies across six areas (Caena & Redecker, 2019). These frameworks inform both research and policy, including India's (National Education Policy, 2020) which emphasizes technology integration and the establishment of a National Educational Technology Forum (Ministry of Education, 2020).

Despite growing attention to pre-service teachers' digital competencies, the research landscape remains fragmented. Studies employ varying definitions, assessment instruments, and methodological approaches, complicating synthesis and comparison. This systematic review addresses this gap by comprehensively examining empirical research on pre-service teachers' digital pedagogical competencies from 2018 to 2024. The review aims to:

- Identify and analyse dominant theoretical frameworks.
- Synthesize findings on competence levels and dimensions.
- Examine factors influencing competence development.
- Evaluate assessment approaches and methodological quality.
- Derive implications for teacher education programmes and future research.

II. LITERATURE REVIEW

2.1. Conceptualizing digital pedagogical competence

Digital pedagogical competence represents a complex, multidimensional construct. Early conceptualizations focused on technical ICT skills, but contemporary understanding emphasizes the integration of technology with pedagogical and content expertise. The TPACK framework, building on (Shulman, 1986) pedagogical content knowledge, identifies seven knowledge domains including technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), and their intersections (Mishra & Koehler, 2006). TPACK has generated extensive empirical research, with meta-analyses confirming its utility while noting measurement challenges (Schmid et al., 2024).

The DigCompEdu framework offers an alternative lens, organizing educator digital competence into six areas: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence (Redecker, 2017). This framework distinguishes educators' competencies from general digital citizenship, recognizing the specific demands of educational contexts. Research employing DigCompEdu has proliferated following its 2017 publication, particularly in European contexts (Caena & Redecker, 2019).

Additional frameworks include UNESCO's ICT Competency Framework for Teachers, the ISTE Standards for Educators, and various national frameworks. (Tomczyk & Fedeli ,2021) mapped these frameworks, identifying convergence around technical skills, pedagogical integration, ethical awareness, and continuous professional development. However, significant variation exists in how frameworks conceptualize the relationship between generic digital competence and profession-specific pedagogical application.

2.2. Factors influencing pre-service teacher digital competence

Research identifies multiple factors shaping pre-service teachers' digital competence development. (Ertmer, 1999) influential distinction between first-order (external) and second-order (internal) barriers remains relevant. External factors include access to technology, infrastructure quality, curriculum design, and institutional support. Internal factors encompass attitudes, self-efficacy beliefs, pedagogical beliefs, and prior technology experiences (Pozas, 2023).

Self-efficacy has emerged as a particularly significant predictor. Meta-analytic evidence demonstrates robust positive relationships between technology integration self-efficacy and TPACK dimensions (Zeng et al., 2022; Bandura, 1977) self-efficacy theory suggests that mastery experiences, vicarious learning, social persuasion, and physiological states influence efficacy beliefs. Teacher education programmes can leverage these sources through authentic technology-enhanced teaching experiences, modelling by faculty, and supportive learning environments.

Training approaches significantly influence competence development. (Tondeur et al., 2012) identified effective strategies including: alignment of technology integration with educational theory and practice, modelling by teacher educators, reflection on attitudes toward technology, learning technology by design, and collaboration among pre-service teachers. More recently, research emphasizes the importance of authentic practicum experiences where candidates apply digital competencies in real classroom contexts (König et al., 2020).

III. METHODS

3.1. Review protocol and PRISMA guidelines

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). A review protocol was developed specifying research questions, eligibility criteria, search strategy, and analysis procedures. The review synthesized both quantitative and qualitative findings through thematic synthesis methodology (Thomas & Harden, 2008).

3.2. Search strategy and databases

Systematic searches were conducted across four academic databases: SCOPUS, Web of Science, ERIC, and Education Source. Search terms combined concepts related to pre-service teachers (pre-service teacher OR student teacher OR teacher candidate OR trainee teacher), digital competence (digital competence OR digital literacy OR ICT competence OR TPACK OR technological pedagogical content knowledge OR digital skills OR DigCompEdu), and teacher education (teacher education OR teacher preparation OR teacher training). Searches were limited to peer-reviewed journal articles published in English between January 2018 and December 2024.

3.3. Inclusion and exclusion criteria

Studies were included if they:

- Focused on pre-service teachers in initial teacher education programmes
- Examined digital pedagogical competencies including tpack, digital literacy for teaching, or technology integration skills
- Employed empirical research methods (quantitative, qualitative, or mixed)
- Were published in peer-reviewed journals

Studies were excluded if they:

- Focused exclusively on in-service teachers
- Addressed general digital literacy without pedagogical focus;
- Were theoretical or conceptual papers without empirical data; or
- Were conference proceedings, dissertations, or book chapters.

3.4. Study selection and data extraction

Initial database searches yielded 1,847 records. Following duplicate removal (n=423), 1,424 records underwent title and abstract screening. Full-text assessment was conducted for 186 potentially eligible articles. After applying exclusion criteria, 78 studies were included in the final review. Data extraction captured: study characteristics (country, sample, design), theoretical framework, competence dimensions assessed, measurement instruments, key findings, and methodological quality indicators.

3.5. Analysis approach

Thematic synthesis was employed to integrate findings across heterogeneous studies. This involved:

- Line-by-line coding of findings sections
- Development of descriptive themes capturing patterns within studies
- Generation of analytical themes through interpretive synthesis (thomas & Harden, 2008).

Quantitative findings were synthesized narratively, as meta-analysis was precluded by heterogeneity in measures and outcome definitions.

IV. RESULTS

4.1. Characteristics of included studies

The 78 included studies represented diverse geographical contexts, with concentrations in Turkey (n=14), Spain (n=9), China (n=8), United States (n=7), Germany (n=6), and Indonesia (n=5). Quantitative designs dominated (n=52, 67%), followed by mixed methods (n=18, 23%) and qualitative approaches (n=8, 10%). Sample sizes ranged from 17 to 2,011 pre-service teachers, with median sample of 287. Publication trends showed acceleration following the COVID-19 pandemic, with 47 studies (60%) published between 2020 and 2024.

4.2. Theoretical frameworks employed

TPACK emerged as the most prevalent framework (n=48, 62%), often combined with Technology Acceptance Model constructs. DigCompEdu was employed in 18 studies (23%), predominantly in European research. Several studies utilized multiple frameworks or developed hybrid models. Notably, (Schmid et al., 2024) conducted a systematic review of TPACK reviews, identifying conceptual drift and measurement inconsistencies across studies. Despite framework prevalence, significant variation existed in operationalization, with studies emphasizing different TPACK dimensions or DigCompEdu competence areas.

4.3. Digital competence levels and dimensions

Synthesis revealed consistent patterns regarding pre-service teachers' competence profiles. Technological Knowledge (TK) typically demonstrated the highest self-reported levels, reflecting participants' familiarity with digital tools for personal use. However, Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPCK) showed notably lower levels, indicating challenges in applying technological skills pedagogically (Schmid et al., 2020). Studies employing DigCompEdu similarly found higher competence in digital resources (Area 2) compared to assessment (Area 4) and empowering learners (Area 5) (Çebi & Reisoğlu, 2022).

(Zeng et al., 2025) identified five major influencing dimensions in their recent systematic review: training and curriculum practice support, psychological and environmental support, policy systems and resource environments, legal ethics and digital literacy, and individual characteristics. Significant disparities were observed between foundational digital competencies and higher-order capabilities including ethical awareness, critical thinking, and pedagogical integration.

Table 1: Summary of Digital Competence Dimensions Across Studies

Competence Dimension	TPACK Equivalent	DigCompEdu Area	Studies (n)
Technical skills	TK	Area 2	68
Pedagogical integration	TPK, TPCK	Area 3	54
Digital assessment	TPK	Area 4	32
Self-efficacy/attitudes	—	Area 1	41
Digital ethics/safety	—	Area 6	19

Note: TK = Technological Knowledge; TPK = Technological Pedagogical Knowledge; TPCK = Technological Pedagogical Content Knowledge

4.4. COVID-19 pandemic impacts

The COVID-19 pandemic emerged as a significant contextual factor in post-2020 studies. Research documented what (Howard et al.,2022) termed the 'Great Online Transition,' forcing rapid development of digital teaching competencies. Studies found that while the pandemic accelerated digital competence development, it also exposed significant disparities in readiness and infrastructure (König et al., 2020). Pre-service teachers reported increased competence in basic digital tools but continued challenges with pedagogical integration and virtual classroom management (Pourdavood & Song, 2021).

Comparative studies indicated that pre-service teachers' self-perceived competence increased during the pandemic period, though this growth was uneven across competence dimensions. Teachers with no prior online teaching experience reported greater perceived competence gains than those with previous experience (Lähteenmäki et al., 2022). However, qualitative research revealed anxiety and concerns about readiness for face-to-face teaching following predominantly online preparation (Rahman et al., 2022).

4.5. Factors influencing competence development

Thematic synthesis identified five clusters of factors influencing pre-service teachers' digital competence development. First, training and curriculum design emerged as critical, with integrated approaches combining technology with pedagogy proving more effective than standalone ICT courses. Authentic learning experiences, including technology-enhanced microteaching and practicum placements, demonstrated significant positive impacts (Tondeur et al., 2020).

Second, psychological factors including self-efficacy, attitudes, and pedagogical beliefs showed consistent associations with competence levels. (Aslan et al., 2025) found that digital literacy mediated 56% of TPACK's total effect on twenty-first-century teaching competencies, highlighting the interconnection between these constructs. Third, institutional support including infrastructure, faculty modelling, and collaborative learning environments facilitated development. Fourth, individual characteristics including gender, prior technology experience, and subject specialization moderated competence levels, though findings were inconsistent across studies. Fifth, policy and resource environments influenced both access and motivation for competence development.

4.6. Assessment approaches and methodological quality

Self-report surveys dominated assessment approaches, employed in 71 studies (91%). Validated instruments included the TPACK-21 scale, DigCompEdu Check-In, and various researcher-developed questionnaires. Only seven studies incorporated performance-based measures, such as lesson plan analysis or technology-enhanced teaching demonstrations. This methodological limitation constrains the validity of findings, as self-reported competence may diverge from actual capability. (Schmid et al., 2020) found that TPACK profiles were unrelated to actual technology use in lesson plans, underscoring the need for objective assessment approaches.

V. DISCUSSION

This systematic review synthesizes empirical evidence on pre-service teachers' digital pedagogical competencies from 2018 to 2024. Several significant findings emerge with implications for research, policy, and practice.

First, while TPACK remains dominant, the proliferation of frameworks and their inconsistent operationalization complicates knowledge accumulation. The conceptual drift identified by (Schmid et al., 2024) in their review of reviews suggests the need for greater precision in how digital pedagogical competence is defined and measured. The DigCompEdu framework offers advantages in specificity and practical applicability, but its limited adoption outside European contexts constrains comparability.

Second, the persistent gap between technological familiarity and pedagogical integration highlights the inadequacy of technocentric approaches to teacher preparation. Pre-service teachers' strength in foundational digital skills does not automatically translate to competent technology-enhanced teaching. This finding aligns with (Koehler & Mishra,2009) original TPACK conceptualization and underscores the importance of integrated curriculum approaches that situate technology within authentic pedagogical contexts.

Third, the COVID-19 pandemic represented both a catalyst and a disruptor for digital competence development. While forced online teaching accelerated certain competencies, it also exposed disparities and created anxiety about comprehensive teaching readiness. Post-pandemic teacher education must balance continued digital competence development with attention to the full spectrum of pedagogical skills required for diverse teaching contexts.

Fourth, the predominance of self-report methodologies represents a significant limitation. The disconnect between self-perceived competence and observable performance documented by (Schmid et al., 2020) suggests that future research should incorporate authentic assessment approaches including technology-enhanced teaching observations, portfolio assessments, and competency-based evaluations.

For the Indian context specifically, the National Education Policy 2020's emphasis on technology integration and the proposed National Educational Technology Forum provide an enabling policy environment. However, implementation requires attention to infrastructure disparities, faculty digital competence, and curriculum redesign aligned with both TPACK principles and DigCompEdu frameworks. The four-year Integrated Teacher Education Programme (ITEP) mandated by NEP 2020 offers opportunities to embed technology-enhanced pedagogy throughout teacher preparation rather than confining it to isolated ICT courses.

VI. CONCLUSION

This systematic review provides a comprehensive synthesis of research on pre-service teachers' digital pedagogical competencies from 2018 to 2024. The analysis of 78 empirical studies reveals a maturing but still fragmented research field. Key conclusions include:

- TPACK and DigCompEdu frameworks dominate but require more consistent operationalization
- Pre-service teachers demonstrate adequate foundational digital skills but weaker pedagogical integration capabilities
- The COVID-19 pandemic accelerated competence development while exposing disparities
- Self-efficacy, integrated training approaches, and authentic practicum experiences emerge as key influencing factors
- Methodological limitations, particularly reliance on self-report measures, constrain validity of findings.

Recommendations for teacher education programmes include: adopting integrated rather than standalone approaches to digital pedagogy; providing authentic technology-enhanced practicum experiences; developing faculty digital competencies to enable effective modelling; incorporating reflection on pedagogical beliefs and attitudes; and implementing authentic assessment approaches beyond self-report surveys. Future research should prioritize longitudinal designs tracking competence development, comparative studies across cultural contexts, and performance-based assessment methodologies.

As educational systems continue to evolve in the post-pandemic era, preparing digitally competent teachers becomes increasingly critical. This review provides a foundation for evidence-based approaches to developing pre-service teachers' digital pedagogical competencies, ultimately serving the goal of enhanced teaching quality and student learning outcomes.

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