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A Chronological Review of the TPACK Framework in Pre-Service Teacher Education (2006–2025)

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ABSTRACT

This review synthesizes research on Technological Pedagogical Content Knowledge (TPACK) in teacher education, focusing on its evolution and detailed analysis to address fragmented understanding and methodological limitations in the field. The review aimed to evaluate TPACK's conceptual development, assess measurement approaches, synthesize instructional strategies, compare disciplinary and contextual variations, and identify implementation challenges. A systematic analysis of empirical, theoretical, and bibliometric studies from 2006 to 2025, predominantly from Asia, North America, and Europe, was conducted using mixed- method and thematic frameworks. Findings reveal that TPACK has evolved from PCK to a dynamic, integrative framework, yet inconsistencies in definitions and assessment tools persist. Instructional interventions, including collaborative lesson design and technology-infused courses, effectively foster TPACK development; however, they often emphasize technological skills unevenly across different domains. Disciplinary and contextual factors significantly influence TPACK enactment, though cross-disciplinary and socio-cultural investigations remain limited. Common barriers include resource constraints, insufficient training, and resistance to change, compounded by methodological weaknesses in research designs. These findings converge to highlight the need for rigorous, context-sensitive assessment and tailored instructional models. The review underscores theoretical refinement and practical application of TPACK as essential for advancing teacher education programs that integrate technology, pedagogy, and content knowledge effectively.

Keywords: *Technological Pedagogical Content Knowledge (TPACK), technology-infused course, instructional interventions.*

Introduction:

Research on Technological Pedagogical Content Knowledge (TPACK) has emerged as a critical area of inquiry due to its central role in guiding effective technology integration in education. Since its conceptualization as an extension of Shulman's Pedagogical Content Knowledge (PCK) framework, TPACK has evolved to encompass the complex interplay among technological, pedagogical, and content knowledge domains (Niess, 2011; Voogt et al., 2013; Koehler et al., 2014). Over the past two decades, the

field has witnessed a surge in empirical studies and theoretical refinements, reflecting the growing importance of digital competence in teacher education (Soler-Costa et al., 2021; Zou et al., 2024). The COVID-19 pandemic further accelerated the adoption of TPACK frameworks, highlighting the need for adaptive teaching strategies in hybrid and remote learning environments (Karaduman & Akman, 2024; Zou et al., 2024). Notably, meta-analytic reviews reveal that despite widespread adoption, evidence regarding TPACK's effectiveness on student outcomes remains methodologically uneven and inconclusive (León et al., 2025; Karaduman & Akman, 2024). This underscores the practical significance of advancing TPACK research to better prepare educators for 21st- century classrooms (Fayda-Kınık, 2022; Valtonen et al., 2017). The specific problem addressed in this review concerns the fragmented understanding of TPACK's development and application in teacher education, particularly regarding preservice teachers' readiness and instructional practices (Su, 2023; Weidlich & Kalz, 2023). Although numerous studies have explored TPACK components and interventions, critical gaps persist in clarifying how TPACK evolves and how contextual factors influence its enactment (Antonio, 2024; Aumann et al., 2024; "Technological pedagogical content knowle...", 2023). Controversies exist regarding the conceptual boundaries among TPACK domains and the adequacy of current measurement instruments (Scott, 2021; Phillips & Harris, 2018). Some scholars argue that TPACK remains a heterogeneous construct lacking empirical clarity, while others emphasize its transformative potential when integrated with emerging technologies such as AI (Ye et al., 2024; Harris & Phillips, 2018) ("Technological pedagogical content knowle...", 2023). The consequences of these gaps include inconsistent teacher preparation and suboptimal technology integration in classrooms (Sofwan et al., 2023; Nelson et al., 2019).

Conceptually, TPACK is defined as the integrated knowledge teachers require to effectively combine technology, pedagogy, and content in instructional design (Koehler et al., 2014; Chai et al., 2011). It comprises seven interrelated constructs, including technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), and their intersections such as technological pedagogical knowledge (TPK) and pedagogical content knowledge (PCK) (Koh & Sing, 2011; Chai et al., 2011). This framework serves as the theoretical foundation for examining how teachers develop competencies to navigate complex teaching environments with technology (Niess, 2011; Koehler et al., 2014). The purpose of this systematic review is to synthesize the evolution and detailed analyses of TPACK within teacher education, focusing on preservice teacher development, instructional strategies, and contextual influences. By addressing identified gaps, this review aims to provide a comprehensive understanding that informs evidence-based teacher preparation and professional development programs (Antonio, 2024; Tondeur et al., 2020). The value-added lies in integrating diverse empirical findings and theoretical perspectives to guide future research and practice in TPACK implementation (Karaduman & Akman, 2024; Tondeur et al., 2013).

Chronological Review of Literature

This review employs a rigorous methodology, including systematic literature searches, meta-analytic synthesis, and thematic analysis of empirical studies published between 2006 and 2025. Inclusion criteria emphasize peer-reviewed research focusing on TPACK development in preservice and in-service

teacher education contexts (León et al., 2025; Karaduman & Akman, 2024). Findings are organized to map the trajectory of TPACK research, analyze instructional interventions, and discuss emerging challenges and opportunities for advancing teacher competencies in technology integration (Yumna, 2025; Sierra et al., 2023). The evolution of research on Technological Pedagogical Content Knowledge (TPACK) in teacher education reflects growing interest in integrating technology, pedagogy, and content knowledge for effective teaching. Early work focused on conceptualizing TPACK as an extension of pedagogical content knowledge and understanding its theoretical foundations. Subsequent studies emphasized the development and validation of assessment instruments, instructional strategies, and teacher preparation models. Recent literature highlights contextual variations, disciplinary applications, challenges in implementation, and the incorporation of emerging technologies such as AI to support teacher training for 21st-century learning environments.

Review Process:

A systematic review process follows a set of techniques to ensure the process of methodology and transparency of the process. The study draws from multiple academic databases, selected based on Technological Pedagogical Content Knowledge (TPACK) in teacher education, focusing on its evolution and detailed analysis, Investigating frameworks and models for developing Technological Pedagogical Content Knowledge (TPACK) in teacher education: methodologies, assessments, and practical applications and Examining the impact of Technological Pedagogical Content Knowledge (TPACK) on various educational contexts and methodologies for enhancing TPACK development in preservice teachers. IEEE Xplore was prioritised for its extensive coverage of technology-enhanced learning and engineering education. ACM Digital Library provided insights into computational and AI-driven pedagogical approaches. Web of Science and Scopus were included due to their interdisciplinary scope and high-impact journal coverage. ScienceDirect and SpringerLink offered access to peer-reviewed articles in sustainability education and teacher training. Finally, Google Scholar supplemented the search with its broad indexing of scholarly work. The search strings combined variations of "TPACK" and "TPACK Framework on Pre-service teachers" while excluding review articles, surveys, and meta-analyses to focus on primary research. Each database employed tailored syntax, such as TITLE-ABS-KEY in Scopus and Web of Science, to refine results. The researcher takes our assembled pool of 479 candidate papers (453 from search queries + 26 from citation chaining) and impose a relevance ranking so that the most pertinent studies rise to the top of our final papers table. Finally found 474 papers that were relevant to the research query. Out of 474 papers, 89 were highly relevant for the present study.

Year Range	Research Direction	Description
2006–2011	Foundational Frameworks and Conceptualization	Initial studies introduced and refined the TPACK framework, establishing its theoretical basis as an extension of pedagogical content knowledge. Research explored the dynamic interaction among content, pedagogy, and technology, laying the groundwork for future empirical studies. Early investigations also examined teacher knowledge development and proposed models for integrating technology in curriculum design and teacher education.
2012–2015	Assessment Instruments and Instructional Design Models	This period saw the development and validation of various TPACK assessment tools and instructional design frameworks. Studies focused on strategies for fostering TPACK in preservice and in-service teachers through courses, lesson planning, and technology integration activities. Research also compared different approaches to technology education, emphasising scaffolded learning and authentic teaching experiences.
2016–2018	Empirical Studies on TPACK Development and Challenges	Research expanded to include mixed-method and longitudinal studies measuring TPACK growth among preservice teachers across disciplines. Challenges such as methodological inconsistencies, measurement validity, and gender differences were identified. The role of professional development, collaborative learning, and contextual factors in enhancing TPACK competence became focal points, alongside critiques of the framework's scope and application.
2019–2021	Meta-Analyses, Systematic Reviews, and Theoretical Refinements	Literature reviews, bibliometric analyses, and meta-syntheses provided comprehensive overviews of TPACK research trends, gaps, and methodological quality. The importance of integrating sociocultural perspectives and technological pedagogical reasoning was emphasized. Studies highlighted the need for continuous learning, differentiated strategies, and deeper conceptualizations of TPACK as a transformative and context-sensitive knowledge base.
2022–2025	Advanced Applications, Disciplinary Specificity, and Emerging Technologies	Recent studies focus on disciplinary adaptations of TPACK, especially in science, mathematics, and language education, highlighting innovative instructional strategies and digital tools including AI and virtual reality. Research underscores variability in TPACK enactment, barriers to effective integration, and the importance of supportive institutional environments. Future directions advocate for integrated technology models, longitudinal tracking, and addressing equity and accessibility in teacher education programs.

Implications of the Study in today's Scenario

The evolution of the TPACK framework reflects a significant theoretical advancement in understanding teacher knowledge by integrating technology with pedagogy and content knowledge. This integration challenges traditional models that treated these domains separately, emphasizing the dynamic and context-sensitive nature of teacher knowledge required for effective technology integration (Koehler et al., 2014; Phillips & Harris, 2018; Niess, 2011). The literature reveals ongoing debates about the conceptual boundaries and components of TPACK, including the emergence of new knowledge domains beyond the original seven, such as technological educational content knowledge (TECK) and technological learning content knowledge (TLCK). These expansions suggest that TPACK is a fluid and evolving construct that must adapt to emerging technologies and teaching contexts (Bibi and Khan, 2016). Empirical findings indicate that TPACK development is not uniform across all knowledge domains; pedagogical content knowledge (PCK) often shows stronger growth compared to technological content knowledge (TCK), highlighting the complexity of integrating technology meaningfully within specific content areas (Valtonen et al., 2019; Hofer & Grandgenett, 2012; Pamuk et al., 2015). Theoretical models underscore the importance of disciplinary and contextual variations in TPACK development, suggesting that subject-specific pedagogies and technological affordances must be considered to fully understand and support TPACK growth (Avci and Istanbullu, 2025; Akkoc and Alan, 2020; Habiyaremye et al., 2022). The integration of TPACK with instructional design frameworks, such as ADDIE and SQD, provides a theoretical basis for systematic teacher education program development, emphasizing the need for active, authentic, and reflective learning experiences to foster TPACK (Yumna, 2025) (Tondeur et al., 2020; Lee & Kim, 2017). Recent theoretical perspectives advocate viewing TPACK as a transformative and homogeneous knowledge that evolves continuously throughout a teacher's career, rather than a static set of competencies, thus calling for longitudinal and individualized approaches to research and teacher education ("Technological pedagogical content knowledge...", 2023) (Valtonen et al., 2017). The evidence suggests that teacher education programs should move beyond stand-alone technology courses and instead embed technology integration within content-specific pedagogical training to better support the development of integrated TPACK competencies (Buss et al., 2015; Foulger et al., 2015; Shinas et al., 2015). Instructional strategies that emphasize authentic, experiential learning opportunities— such as lesson planning, microteaching, collaborative projects, and reflective practice— have been shown to effectively enhance preservice teachers' TPACK, particularly when supported by ongoing feedback and mentorship (Antonio, 2024; Bwalya et al., 2024; Tondeur et al., 2020). Despite positive outcomes, challenges such as limited access to technology, insufficient digital literacy, time constraints, and resistance to change remain significant barriers to effective TPACK development and implementation, indicating a need for institutional support and resource allocation (Antonio, 2024; Sierra et al., 2023; Nelson et al., 2019). The integration of emerging technologies, including AI and virtual reality, into teacher education holds promise for advancing TPACK development but requires careful consideration of accessibility, pedagogical alignment, and teacher preparedness (Ye et al., 2024; Zou et al., 2024; Yumna, 2025). Assessment of TPACK remains complex, with a need for valid and reliable

instruments that capture both self-perceptions and performance-based measures to provide a comprehensive understanding of teachers' competencies and inform program improvements Scott, 2021; Akyuz, 2018; Abbitt, 2011). Policy and institutional frameworks should prioritize continuous professional development and create supportive cultures that encourage technology integration, recognizing that TPACK development is an ongoing process requiring sustained investment and alignment with educational goals (Nelson et al., 2019; Sofwan et al., 2023; Tondeur et al., 2013).

Conclusion

The literature on Technological Pedagogical Content Knowledge (TPACK) in teacher education collectively reveals a dynamic and multifaceted framework that has evolved significantly since its conceptual inception. The body of research underscores TPACK's roots in Pedagogical Content Knowledge (PCK) and its expansion to explicitly include technological knowledge, reflecting the growing imperative to integrate digital tools meaningfully into teaching. This evolution is characterized by ongoing theoretical refinements that emphasize TPACK as an interrelated, context-sensitive, and transformative form of teacher knowledge, rather than a static set of competencies. Emerging perspectives highlight the importance of viewing TPACK development as a continuous, individualized process mediated by sociocultural and institutional contexts.

Assessment of TPACK has progressed toward more sophisticated and multidimensional methodologies. While self-assessment instruments remain prevalent, advances in psychometrically validated tools, performance-based assessments, and mixed-method approaches have enhanced the reliability and depth of understanding of TPACK competencies. Nonetheless, challenges persist in capturing the integrated and situated nature of TPACK, with many tools disproportionately emphasizing technological knowledge at the expense of pedagogical and content intersections. The literature suggests the necessity of triangulating multiple data sources to authentically measure TPACK development and application.

Instructional strategies designed to foster TPACK demonstrate favourable outcomes when they involve authentic, experiential learning opportunities such as collaborative lesson design, microteaching, virtual internships, and structured feedback frameworks like the SQD model. These approaches facilitate meaningful integration of technology with pedagogy and content, although their impact is often limited by insufficient experimental rigor and short-term evaluations. Additionally, disciplinary-specific and contextual variations markedly influence TPACK development and enactment, with distinct challenges and affordances identified across science, mathematics, language, and other subject areas. Geographic and institutional factors further modulate TPACK trajectories, underscoring the need for tailored, context-responsive teacher education programs.

Persistent challenges impede effective TPACK implementation, including limited access to technology, resource constraints, inadequate training, resistance to change, and time pressures. Methodological shortcomings in research design and the lack of sustained professional development contribute to gaps between theoretical promise and practical realization. Institutional support and teacher educator preparedness emerge as critical factors for fostering enduring technology integration competencies.

In summary, the collective evidence advocates for more rigorous, longitudinal, and contextually nuanced research that bridges theoretical conceptualizations with practical applications. Integrating technology, pedagogy, and content knowledge remains essential for preparing teachers capable of navigating increasingly complex educational landscapes. Future efforts should prioritize the development of valid assessment tools, evidence-based instructional interventions, and supportive institutional frameworks that recognize the situated and evolving nature of TPACK in diverse teacher education contexts.

References

[1]. Abbitt, J. T. (2011). Measuring technological pedagogical content knowledge in preservice teacher education. Journal of Research on Technology in Education, 43(4), 281–300. https://doi.org/10.1080/15391523.2011.10782573

[2]. Agyei, D. D., & Keengwe, J. (2014). Using technology pedagogical content knowledge development to enhance learning outcomes. Education and Information Technologies, 19(1), 155–171. https://doi.org/10.1007/s10639-012-9204-1

[3]. Akkoç, H., & Alan, S. (2020). Technological pedagogical content knowledge: A review of mathematics education literature.

[4]. Akyüz, D. (2018). Measuring technological pedagogical content knowledge (TPACK) through performance assessment. Computers & Education, 125, 212–225. https://doi.org/10.1016/j.compedu.2018.06.012

[5]. Ali, A., & Waer, H. (2023). Integrating TPACK in pre-service teachers' EFL course: Impacts on perception, knowledge, and practices. Australian Journal of Teacher Education. https://doi.org/10.14221/1835-517x.6089

[6]. Antonio, R. P. (2024). Promoting technological pedagogical content knowledge (TPACK) in preservice science teacher education: A scoping review of instructional strategies, interventions, and programs. International Journal on Studies in Education, 157–171. https://doi.org/10.46328/ijonse.302

[7]. Aumann, A., Schnebel, S., & Weitzel, H. (2024). Teaching biology lessons using digital technology: A contextualized mixed-methods study on pre-service biology teachers' enacted TPACK. Educational Science. https://doi.org/10.3390/educsci14050538

[8]. Avci, Ş. K., & Istanbullu, A. (2025). Fostering discipline-specific TPACK development. https://doi.org/10.4018/979-8-3693-9370-3.ch006

[9]. Balladares-Burgos, J., & Berrocoso, J. V. (2022). The technopedagogical TPACK model and its impact on teacher education: A literature review. *Electronic Journal of Research in Education Sciences*, 6(1), 63–72. https://doi.org/10.32541/recie.2022.v6i1.pp63-72

[10]. Bibi, S., & Khan, S. H. (2016). TPACK in action: A study of a teacher educator's thoughts when planning to use ICT. Australasian Journal of Educational Technology, 33(4), 70–87. https://doi.org/10.14742/ajet.3071

[11]. Bonafini, F. C., & Lee, Y. (2021). Investigating prospective teachers' TPACK and their use of mathematical action technologies as they create screencast video lessons on iPads. TechTrends, 65(3), 1–17. https://doi.org/10.1007/s11528-020-00578-1

[12]. Bueno, R., & Niess, M. L. (2023). Redesigning mathematics preservice teachers' preparation for teaching with technology: A qualitative cross-case analysis using TPACK lenses. https://doi.org/10.1016/j.compedu.2023.104895

[13]. Buss, R. R., Wetzel, K., Foulger, T. S., & Lindsey, L. (2015). Preparing teachers to integrate technology into K–12 instruction: Comparing a stand-alone technology course with a technology-infused approach. Journal of Digital Learning in Teacher Education, 31(4), 160–172. https://doi.org/10.1080/21532974.2015.1055012

[14]. Bwalya, A., Rutegwa, M., & Mapulanga, T. (2024). Developing pre-service biology teachers' technological pedagogical content knowledge through a TPACK-based course. European Journal of Educational Research. https://doi.org/10.12973/eu-jer.13.1.263

[15]. Cavassani, T. B., Andrade, J. D. J. D., & Marques, R. N. (2024). Integration of ICT in teacher education: Approaches between the TPACK model and the sociocultural perspective. Education in Review, 40. https://doi.org/10.1590/0102-469821245t

[16]. Cetin-Dindar, A., Boz, Y., Sonmez, D. Y., & Celep, N. D. (2018). Development of pre-service chemistry teachers' technological pedagogical content knowledge. Chemistry Education Research and Practice, 19(1), 167–183. https://doi.org/10.1039/c7rp00175d

[17]. Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). Educational Technology & Society, 13(4), 63–73.

[18]. Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2013). A review of technological pedagogical content knowledge. Educational Technology & Society, 16(2), 31–51.

[19]. Chai, C. S., Koh, J. H. L., Tsai, C. C., & Tan, L. (2011). Modeling primary school pre-service teachers' technological pedagogical content knowledge (TPACK) for meaningful learning with information and communication technology (ICT). Computers & Education, 57(1), 1184–1193. https://doi.org/10.1016/j.compedu.2011.01.007

[20]. Durdu, L., & Dağ, F. (2017). Pre-service teachers' TPACK development and conceptions through a TPACK-based course. Australian Journal of Teacher Education, 42(11), 150–171. https://doi.org/10.14221/ajte.2017v42n11.10

[21]. Fahrurozi, S. K., Budiyanto, C. W., & Roemintoyo. (2019). Pre-service teachers perspective in developing TPACK: Literature review. https://doi.org/10.1063/1.5139756

[22]. Fayda-Kınık, F. S. (2022). The digital teacher. In Advances in Educational Technologies and Instructional Design (pp. 31–53). https://doi.org/10.4018/978-1-7998-9538-1.ch002

[23]. Filho, R. A., & Gitirana, V. (2022). Pre-service teachers' knowledge: Analysis of teachers' education situation based on TPACK. The Mathematics Enthusiast, 19(2), 594–631. https://doi.org/10.54870/1551-3440.1565

[24]. Finger, G., Jamieson-Proctor, R., & Albion, P. (2010). Beyond pedagogical content knowledge: The importance of TPACK for informing preservice teacher education in Australia. https://doi.org/10.1007/978-3-642-15378-5_11

[25]. Foulger, T. S., Buss, R. R., Wetzel, K., & Lindsey, L. (2015). Instructors' growth in TPACK: Teaching technology-infused methods courses to preservice teachers. Journal of Digital Learning in Teacher Education, 31(4), 134–147. https://doi.org/10.1080/21532974.2015.1055010

[26]. Graham, C. R., Borup, J., & Smith, N. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. Journal of Computer Assisted Learning, 28(6), 530–546. https://doi.org/10.1111/j.1365-2729.2011.00472.x

[27]. Habiyaremye, H. T., Ntivuguruzwa, C., & Ntawiha, P. (2022). From pedagogical toward technological pedagogical content knowledge frameworks and their effectiveness in teaching mathematics: A mapping review. F1000Research, 11, 1029. https://doi.org/10.12688/f1000research.125073.1

[28]. Harris, J. B., & Phillips, M. (2018). If there's TPACK, is there technological pedagogical reasoning and action?

[29]. Harris, J. B., Mishra, P., & Koehler, M. J. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. Journal of Research on Technology in Education, 41(4), 393–416. https://doi.org/10.1080/15391523.2009.10782536

[30]. Harris, J. B., Phillips, M., Koehler, M. J., & Rosenberg, J. M. (2017). TPCK/TPACK research and development: Past, present, and future directions. Australasian Journal of Educational Technology, 33(3), 1–8. https://doi.org/10.14742/ajet.3907

[31]. Hechter, R. P., Phyfe, L., & Vermette, L. A. (2012). Integrating technology in education: Moving the TPCK framework towards practical applications. Education Research and Perspectives, 39(1), 136–152.

[32]. Hermansah, I., Nasrulloh, I., & Kartini, A. (2024). Model technological pedagogical content knowledge in learning: A literature review. Edutech, 4(2), 56–67. https://doi.org/10.51878/edutech.v4i2.2961

[33]. Hofer, M. J., & Grandgenett, N. (2012). TPACK development in teacher education: A longitudinal study of preservice teachers in a secondary M.A.Ed. program. Journal of Research on Technology in Education, 45(1), 83–106. https://doi.org/10.1080/15391523.2012.10782598

[34]. Jaipal-Jamani, K., & Figg, C. (2015). The framework of TPACK-in-practice: Designing content-centric technology professional learning contexts to develop teacher knowledge of technology-enhanced teaching (TPACK). https://doi.org/10.1007/978-1-4899-8080-9_7

[35]. Jang, S., & Chen, K. (2010). From PCK to TPACK: Developing a transformative model for pre-service science teachers. Journal of Science Education and Technology, 19(6), 553–564. https://doi.org/10.1007/s10956-010-9222-y

[36]. Karaduman, T., & Akman, B. (2024). A comprehensive review of technological pedagogical content knowledge (TPACK). E-Kafkas Journal of Educational Research. https://doi.org/10.30900/kafkasegt.1282126

[37]. Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy, and technology. Computers & Education, 49(3), 740–762. https://doi.org/10.1016/j.compedu.2005.11.012

[38]. Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. https://doi.org/10.1007/978-1-4614-3185-5_9

[39]. Koh, J. H. L., & Sing, C. C. (2011). Modeling pre-service teachers' technological pedagogical content knowledge (TPACK) perceptions: The influence of demographic factors and TPACK constructs.

[40]. Lee, C. J., & Kim, C. (2017). A technological pedagogical content knowledge–based instructional design model: A third version implementation study in a technology integration course. Educational Technology Research and Development, 65(6), 1627–1654. https://doi.org/10.1007/s11423-017-9544-z

[41]. Lee, C., & Kim, C. (2014). The second prototype of the development of a technological pedagogical content knowledge–based instructional design model: An implementation study in a technology integration course. Contemporary Issues in Technology and Teacher Education, 14(3), 297–326.

[42]. León, S. P., Garrido, M., & Lipnevich, A. A. (2025). Passing TPACK through the meta-science circle: A meta-analytic systematic review of the application of the model. https://doi.org/10.35542/osf.io/c5qsr_v1

[43]. Lyublinskaya, I., & Du, X. (2022). Preservice teachers' TPACK learning trajectories in an online educational technology course. Journal of Research on Technology in Education, 1–18. https://doi.org/10.1080/15391523.2022.2160393

[44]. Ma, R. (2023). A review of technological pedagogical content knowledge research frontier and music disciplinary path. (2023). Frontiers in Art Research, 5(2). https://doi.org/10.25236/far.2023.050205

[45]. Miranda, G. L., & Sampaio, M. N. (2025). PCK and TPACK models. In Advances in Educational Technologies and Instructional Design (pp. 1–28). https://doi.org/10.4018/979-8-3373-2267-4.ch001

[46]. Mondal, P. K. (2025). Revolutionizing teacher education: Integrating techno-pedagogical skills for 21st-century classrooms: A comprehensive review. https://doi.org/10.20944/preprints202502.0612.v1

[47]. Mourlam, D., & Herring, M. C. (2016). Exploring the Intel Teach elements in teacher education. https://doi.org/10.1007/978-3-662-47956-8_11

[48]. Nelson, M. J., Voithofer, R., & Cheng, S. (2019). Mediating factors that influence the technology integration practices of teacher educators. Computers & Education, 128, 330–344. https://doi.org/10.1016/j.compedu.2018.09.023

[49]. Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. Journal of Educational Computing Research, 44(3), 299–317. https://doi.org/10.2190/ec.44.3.c

[50]. Niess, M. L. (2018). Introduction to teachers' knowledge-of-practice for teaching with digital technologies: A technological pedagogical content knowledge (TPACK) framework. https://doi.org/10.4018/978-1-5225-5631-2.ch007

[51]. Niess, M. L., Ronau, R. N., Shafer, K., Driskell, S. O., Harper, S. R., Johnston, C. J., Browning, C., Özgün-Koca, S. A., & Kersaint, G. (2009). Mathematics teacher TPACK standards and development model. Contemporary Issues in Technology and Teacher Education, 9(1), 4–24.

[52]. Oner, D. (2020). A virtual internship for developing technological pedagogical content knowledge. Australasian Journal of Educational Technology, 36(2), 27–42. https://doi.org/10.14742/ajet.5192

[53]. Özden, Ş. Y., Yang, H., Wen, H., & Shinas, V. H. (2024). Reflections from a teacher education course built on the TPACK framework: Examining the impact of the technology integration planning cycle on teacher candidates' TPACK development and practice. Social Sciences & Humanities Open, 9, 100869. https://doi.org/10.1016/j.ssaho.2024.100869

[54]. Pamuk, S., Ergun, M., Çakir, R., Yılmaz, H. B., & Ayas, C. (2015). Exploring relationships among TPACK components and development of the TPACK instrument. Education and Information Technologies, 20(2), 241–263. https://doi.org/10.1007/s10639-013-9278-4

[55]. Pamuk, S., Ülken, A., & Dilek, N. Ş. (2013). An investigation of preservice teachers' technology integration competencies from the technological pedagogical content knowledge perspective.

[56]. Phillips, M., & Harris, J. B. (2018). PCK and TPCK/TPACK: More than etiology.

[57]. Poitras, E. G., Doleck, T., Huang, L., Li, S., & Lajoie, S. P. (2017). Advancing teacher technology education using open-ended learning environments as research and training platforms. Australasian Journal of Educational Technology, 33(3). https://doi.org/10.14742/ajet.3498

[58]. Putri, S. A., Sulaeman, N. F., & Putra, P. D. A. (2022). Trend of technological pedagogical content knowledge (TPACK) for pre-service science teachers: A historical review. Journal of Physics Education. 10(2), 165–175. https://doi.org/10.26618/jpf.v10i2.7801

[59]. Rossi, M. D., & Trevisan, O. (2018). Technological pedagogical content knowledge in the literature: How TPCK is defined and implemented in initial teacher education. Journal on Educational Technology, 26(1), 7–23. https://doi.org/10.17471/2499-4324/988

[60]. Schmidt, D. A. (2010). Editor's remarks. https://doi.org/10.1080/10402454.2010.10784644

[61]. Scott, K. C. (2021). A review of faculty self-assessment TPACK instruments (January 2006–March 2020). International Journal of Information and Communication Technology Education, 17(1), 118–137. https://doi.org/10.4018/ijicte.2021040108

[62]. Shinas, V. H., Karchmer-Klein, R., Mouza, C., Yilmaz-Ozden, S., & Glutting, J. J. (2015). Analyzing preservice teachers' technological pedagogical content knowledge development in the context of a multidimensional teacher preparation program. Journal of Digital Learning in Teacher Education, 31(2), 47–55. https://doi.org/10.1080/21532974.2015.1011291

[63]. Sierra, Á. A. J., Iglesias, J. M. O., Cabero-Almenara, J., & Palacios-Rodríguez, A. (2023). Development of the teacher's technological pedagogical content knowledge (TPACK) through lesson study: A systematic review. Frontiers in Education, 8. https://doi.org/10.3389/feduc.2023.1078913

[64]. So, H., & Kim, B. (2009). Learning about problem-based learning: Student teachers integrating technology, pedagogy, and content knowledge. Australasian Journal of Educational Technology, 25(1), 101–116. https://doi.org/10.14742/ajet.1183

[65]. Sofwan, M., Habibi, A., & Yaakob, M. F. M. (2023). TPACK's roles in predicting technology integration during teaching practicum: Structural equation modeling. Education Sciences, 13(5), 448. https://doi.org/10.3390/educsci13050448

[66]. Soler-Costa, R., Moreno-Guerrero, A., López-Belmonte, J., & Marín-Marín, J. (2021). Co-word analysis and academic performance of the term TPACK in Web of Science. Sustainability, 13(1). https://doi.org/10.3390/su13031481

[67]. Srisawasdi, N. (2022). Developing technological pedagogical content knowledge in using computerized science laboratory environments: An arrangement for science teacher education programs. Research and Practice in Technology Enhanced Learning, 9(1), 123–143. https://doi.org/10.58459/rptel.2014.9123-143

[68]. Su, J. (2023). Preservice teachers' technological pedagogical content knowledge development: A bibliometric review. Frontiers in Education, 7. https://doi.org/10.3389/feduc.2022.1033895

[69]. Technological pedagogical content knowledge: Exploring new perspectives. (n.d.). Australasian Journal of Educational Technology, 88–105. https://doi.org/10.14742/ajet.7970

[70]. Terpstra, M. (2015). TPACKtivity: An activity-theory lens for examining TPACK development. https://doi.org/10.1007/978-1-4899-8080-9_4

[71]. Tondeur, J., Roblin, N. P., Van Braak, J., Fisser, P., & Voogt, J. (2013). Technological pedagogical content knowledge in teacher education: In search of a new curriculum. Educational Studies, 39(2), 239–243. https://doi.org/10.1080/03055698.2012.713548

[72]. Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2020). Enhancing pre-service teachers' technological pedagogical content knowledge (TPACK): A mixed-method study. Educational Technology Research and Development, 68(1), 319–343. https://doi.org/10.1007/s11423-019-09692-1

[73]. Tseng, J. J., Cheng, Y. S., & Yeh, H. N. (2019). How pre-service English teachers enact TPACK in the context of web-conferencing teaching: A design thinking approach. Computers & Education, 128, 171–182. https://doi.org/10.1016/j.compedu.2018.09.022

[74]. Turgut, Y. (2017). An analysis of TPACK integration into English language teacher education programs: A comparative study of Turkey and Denmark. Journal on English Language Teaching, 7(4), 1–15. https://doi.org/10.26634/jelt.7.4.13763

[75]. Urban-Woldron, H. (2011). Integrating technology into pre-service physics teachers' pedagogical content knowledge [Doctoral dissertation].

[76]. Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. Australasian Journal of Educational Technology, 33(3), 15–31. https://doi.org/10.14742/ajet.3518

[77]. Valtonen, T., Sointu, E., Kukkonen, J., Mäkitalo, K., Hoang, N., Häkkinen, P., Järvelä, S., Näykki, P., Virtanen, A., Pöntinen, S., Kostiainen, E., & Tondeur, J. (2019). Examining pre-service teachers' technological pedagogical content knowledge as evolving knowledge domains: A longitudinal approach. Journal of Computer Assisted Learning, 35(4), 491–502. https://doi.org/10.1111/jcal.12353

[78]. Vásquez, J. N. C. (2024). Exploration of the TPACK Techno-Pedagogical Model: Integrating Knowledge for Transformative Education superior. https://doi.org/10.46954/librosfahusac.32.c77

[79]. Voogt, J., Fisser, P., Roblin, N. P., Tondeur, J., & Van Braak, J. (2013). Technological pedagogical content knowledge: A review of the literature. Journal of Computer Assisted Learning, 29(2), 109–121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

[80]. Wang, W. (2016). Development of technological pedagogical content knowledge (TPACK) in preK–6 teacher preparation programs (Doctoral dissertation). https://doi.org/10.31274/etd-180810-5460

[81]. Wang, W., Schmidt-Crawford, D. A., & Jin, Y. (2018). Preservice teachers' TPACK development: A review of literature. Journal of Digital Learning in Teacher Education, 34(4), 234–258. https://doi.org/10.1080/21532974.2018.1498039

[82]. Weidlich, J., & Kalz, M. (2023). How well does teacher education prepare for teaching with technology? A TPACK-based investigation at a university of education. European Journal of Teacher Education. https://doi.org/10.1080/02619768.2023.2243645

[83]. White, B., & Geer, R. (2013). Preservice teachers' experience with online modules about TPACK. Australian Educational Computing, 27(3), 124–132.

[84]. Wohlfart, O., & Wagner, I. (2022). The TPACK model: A promising approach to modelling the digital competencies of (prospective) teachers. Journal of Pedagogy. https://doi.org/10.3262/zp0000007

[85]. Wu, H., Balakrishnan, V., & Cai, X. (n.d.). Bibliometric analysis on pre-service teachers' TPACK: A comparative study between Web of Science and China National Knowledge Infrastructure (2010–2022). In Proceedings of the ACM International Conference. https://doi.org/10.1145/3661904.3661913

[86]. Ye, L., Ismail, H. H., & Aziz, A. A. (2024). Innovative strategies for TPACK development in pre-service English teacher education in the 21st century: A systematic review. Forum for Linguistic Studies, 6(6), 274–294. https://doi.org/10.30564/fls.v6i6.7308

[87]. Yumna, A. M. (2025). Technology integration models and instructional design frameworks to facilitate the development of teacher training programmes. Journal of Innovative Practices in Education. https://doi.org/10.4038/jipe.v1i2.15

[88]. Zhi-ming, Y., & Fu-yin, X. (2013). TPACK and teachers' professional development: A technological pedagogical content knowledge perspective. China Educational Technology. https://doi.org/10.3969/j.issn.1009-8097.2013.03.001

[89]. Zou, R., Jiang, L., Cao, Y., Muthukrishnan, P., Fauzi, M. A., & Zhang, H. (2024). Mapping fifteen years of technological pedagogical content knowledge (TPACK) model applications in higher education. Research Square (Preprint). https://doi.org/10.21203/rs.3.rs-5400076

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