Two Decades of TPACK Research in Higher Education: A Global Bibliometric Review from 2006 To 2025

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ABSTRACT

The Technological Pedagogical and Content Knowledge (TPACK) has become a key model for understanding technology integration in higher education, particularly as universities undergo rapid digital transformation. This study conducts a bibliometric analysis of TPACK-related publications in higher education from 2006 to 2025, covering two decades of research since the framework's introduction. Data was retrieved from the Scopus database and analyzed using descriptive bibliometric techniques and science mapping with VOSviewer. The analysis examines publication trends, geographical distribution, subject areas, citation patterns, and keyword co-occurrence networks. Findings indicate a continuous growth in TPACK research, with a notable increase after 2018 and during the post-pandemic period. The United States, China, and Indonesia emerge as leading contributors, while Social Sciences and Computer Science dominate the subject areas. Highly cited studies mainly focus on technology acceptance, digital competence, and teacher readiness. Keyword co-occurrence analysis reveals strong connections between TPACK, higher education, digital competence, online learning, and technology integration. Overall, the findings suggest that TPACK has evolved into a widely applied and interdisciplinary framework in higher education, although gaps remain in its contextual application across disciplines and regions. This study provides insights to inform future research and support the continued development of digital teaching practices in higher education.

Keywords: Bibliometric analysis, digital pedagogy, higher education, TPACK.

1. Introduction

Over the past two decades, the rapid expansion of digital learning ecosystems has fundamentally modified the higher education landscape. Globally, universities are increasingly expected to integrate advanced digital technologies (Aditya et al., 2020; Basilotta-Gómez-Pablos et al., 2022) into teaching, learning, and assessment practices as part of broader digital transformation agendas. This shift has urged the need to understand how higher education instructors develop, apply, and sustain the knowledge required to teach effectively with technology. Beyond technological knowledge, recent higher education research has emphasized that effective teaching also requires a broader set of professional competencies, including communication, interpersonal skills, critical thinking, emotional intelligence, and digital proficiency, which collectively shape educators' ability to integrate technology meaningfully into teaching practices (Saidi & Abd Aziz, 2025).Driven by ongoing technological advancements, increased accessibility to digital tools, and national-level digital education policies, educators are now required to navigate the complex interplay between pedagogy, content, and technology to create meaningful learning experiences for diverse learners (Sanchez, 2020). As traditional pedagogical models are transformed into digitally enhanced contexts, theoretical frameworks that explain the complexity of instructional decision-making have become essential.

The Technological Pedagogical and Content Knowledge (TPACK), introduced by Mishra and Koehler in 2006, has emerged as one of the most influential and widely used models for conceptualizing teachers' technology integration competence. TPACK describes the interplay between three core forms of teacher knowledge (i.e. technology, pedagogy, and content) and articulates how their intersections shape technology enhanced teaching (Mishra & Koehler, 2006). Over time, TPACK has evolved from a conceptual model to a widely adopted research framework used across teacher education, professional development, curriculum design, and digital competence assessment. Many educational systems now embed TPACK competencies into teacher training programs, national ICT in education standards, and digital transformation initiatives. This increasing institutional and policy attention underscores TPACK's central role in guiding digital competence development for educators.

Beyond TPACK, several frameworks such as the European DigCompEdu, ISTE Standards, and the Professional Digital Competence (PDC) model have expanded the conceptualization of digital teaching competence by incorporating elements such as digital ethics, data literacy, accessibility, and institutional support. The models also show the interconnected nature of technology, pedagogy, and subject content in defining digital readiness. These frameworks highlight that effective technology integration requires not only knowledge of pedagogy and content, but also broader competencies related to digital citizenship (Redecker & Punie, 2017). While TPACK offers theoretical understanding of the knowledge intersections, these frameworks provide more towards procedural steps and levels of technology used in teaching and learning. In this context, TPACK continues to function as a foundational model, yet its relationship with emerging digital competence frameworks remains theoretically underexplored. The dominance of TPACK was perceived primarily as cognitive framework, while the occurrence of other complementary frameworks in the literature has conceptually shifted the operationalization of TPACK that requires more holistic towards digital competence as a part of educators' professional profile (Lindfors et al., 2021).

Despite the extensive use of the Technological Pedagogical Content Knowledge (TPACK) in educational research, existing systematic and bibliometric reviews have mainly focused on school education, pre-service teachers, or specific subject domains rather than higher education contexts. For instance, Shabira et al. (2024) reviews TPACK trends specifically in elementary education, while Zou et al. (2022) and Suprapto et al. (2021) did not specify any educational level in their review studies. In fact, these reviews primarily examine conceptual development, measurement approaches, and general research trends in TPACK, often within limited time spans or pedagogical settings that differ substantially from university teaching environments.

The application of TPACK in higher education has been documented as a framework for assessing educators' readiness to integrate technology into their teaching practices. Beyond evaluating individual readiness, TPACK has also been used to examine technology-oriented professional competence, assess the effectiveness of professional development programmes, and explore how digital tools support discipline-specific pedagogical approaches (Cabero & Barroso, 2016). At a broader level, the framework has been applied to understand shifts in instructional practices driven by institutional digital transformation initiatives within higher education. This trajectory was further accelerated during the COVID-19 pandemic, as universities rapidly transitioned to online, blended, and hybrid learning modes. In response, researchers increasingly employed TPACK to explain how educators adapted their teaching strategies, redesigned learning activities, and navigated emerging digital pedagogical challenges (Ali, 2020; Kallou & Kikilia, 2021).

The ecosystem of higher education is characterised by disciplinary diversity, instructional autonomy, and the research–teaching nexus, all of which influence how technology is integrated into teaching practices. Furthermore, unlike school teachers, university educators often enter academia with strong disciplinary expertise but limited formal pedagogical training (Mayasari et al., 2024). Due to these unique characteristics of higher educational institution settings, the application of TPACK might vary in some circumstances. Besides, the use of TPACK in higher education related studies have expanded substantially, incorporating diverse fields such as STEM, humanities, social sciences, vocational education, and professional training (Hsu et al., 2015). More recently, the emergence of generative artificial intelligence (AI), immersive technologies such as VR/AR, and the growing use of learning analytics have transformed scholarly interest in how TPACK can be reconceptualised or extended to remain relevant within rapidly evolving digital networks. The ongoing expansion reflects both the adaptability of the TPACK and the increasing complexity of digital teaching practices in contemporary higher education. Another failing factor to the progress of digital pedagogy in higher education is the COVID-19 pandemic, revealing the need to change and adapt to new digital things and environments (Chen & Hsu, 2022). These contextual differences pointed that TPACK may operate differently in the pedagogical and professional characteristics in higher education compared to structured school environments. As a result, the application of TPACK in higher education pedagogy becomes more complex and context-dependent, requiring a clearer understanding of how the framework has evolved within tertiary education research. Understanding how TPACK scholarship has evolved across higher education is therefore essential for positioning the model within the broader landscape of digital pedagogy.

The significant gap of a focused bibliometric synthesis on TPACK in higher education has resulted in a fragmented understanding of publication patterns, influential contributors, thematic development, and intellectual structures within this field. Addressing this gap, the present study conducts a comprehensive higher-education-focused bibliometric review of TPACK research published between 2006 and 2025 as well as using co-occurrence network analyses. Specifically, the study aims to map the evolution of TPACK research in higher education, identify major research clusters and influential contributions, and examine emerging directions that shape TPACK scholarship at the tertiary level.

To guide the interpretation of bibliometric findings, this study adopts an explicit conceptual framework that links bibliometric indicators to theories of knowledge development and scientific evolution. The growth of publications over time can be understood as reflecting the progression of a research field from its emergence to consolidation and expansion. In this context, increasing publication output indicates the normalization of TPACK as a dominant framework within higher education research, while shifts in thematic focus may signal evolving research paradigms in response to technological and pedagogical change.

In addition, citation analysis is interpreted through the lens of citation network, which views citations as indicators of knowledge diffusion, intellectual influence, and scholarly recognition within a field.

Highly cited publications represent foundational or influential works that shape subsequent research directions, while normalized citation metrics (e.g., citations per year) provide insights into emerging influential studies.

Furthermore, keyword co-occurrence analysis is grounded in knowledge domain evolution models, where co-occurring terms reflect the conceptual structure and thematic organization of a research field. Clusters of keywords represent interconnected research themes, while link strength indicates the degree of conceptual integration across topics. Together, these bibliometric indicators provide a multi-dimensional understanding of how TPACK research in higher education has developed, diversified, and interconnected over time. This framework enables the study to move beyond descriptive mapping toward a more analytical interpretation of the field's intellectual structure and evolution. By integrating these perspectives, the study positions bibliometric analysis not merely as a descriptive tool, but as an analytical approach for examining the dynamics of knowledge production and transformation within higher education research.

To date, bibliometric research on digital pedagogy has been studied in various angles of higher education context. Santoveña-Casal & Lopez (2024) focused on digitalisation, education quality, and university education, and some investigate smart learning (Rad et al., 2025), digital transformation in developing countries (Omar & Abdullahi, 2024) or digital literacy (Barrios-del-Ángel et al., 2026).

This paper eventually focuses on the following specific research objectives:

1. examine the publication output and growth trends of TPACK research in higher education between 2006 and 2025;
2. identify the most influential countries, journals, and authors contributing to TPACK scholarship in higher education;
3. analyse the subject areas characterize TPACK research in higher education;
4. determine the most highly cited publications shaping the development of TPACK research in higher education; and
5. explore the intellectual structure among key TPACK-related concepts and higher education using keyword co-occurrence analysis

To achieve these objectives, the following research questions were considered:

1. RQ1: How has TPACK research in higher education evolved in terms of publication output and growth trends between 2006 and 2025?
2. RQ2: Which countries, journals, and authors have contributed most significantly to TPACK scholarship in higher education?
3. RQ3: What subject areas characterize TPACK research in higher education?
4. RQ4: Which documents have exerted the greatest scholarly influence within the field based on citation patterns?
5. RQ5: How are key concepts related to TPACK and higher education interconnected within the related constructs of literature?

Through performance analysis, co-authorship networks, keyword co-occurrence mapping, and citation formations, this review provides a comprehensive overview of the field's growth, intellectual foundations, and shifting research primacies. By synthesizing approximately two decades of scholarship, the study intents to highlight progress, reveal persistent gaps, and outline opportunities for enhancing TPACK research in higher education as universities continue to deepen their digital transformation initiatives. This technique will be able to show what's been done, what's still missing, and how TPACK research can be advanced in tertiary education. Hence, this study offers timely and critical insights for researchers, educators, policymakers, and institutions seeking to understand how

TPACK has developed and how it can continue to inform digital teaching competence in an era of rapid educational transformation.

2. Methodology

This study employed a bibliometric research design to systematically map the scientific structure, output patterns, and conceptual development of TPACK research, specifically in higher education. Bibliometric methods provide quantitative insights into publication growth, citation patterns, research productivity, and global knowledge structures across identified body of literature. The analysis combined descriptive performance indicators (e.g., publication output, citations, subject areas) with science mapping techniques using VOSviewer. This study analysed bibliographic metadata retrieved from the existing Scopus database and did not involve human participants, personal data, or institutional interventions. Table 1 summarize the correspondence between research questions, data source and bibliometric techniques used in this study. The bibliometric data were retrieved from Scopus database in CSV format including the title, authors, publishers, keywords and others.

Table 1. Correspondence between Research Questions, Data Source, Bibliometric Techniques and Output in Results

Research Question	Data Source	Bibliometric Technique	Output in Results	Theoretical Interpretation
RQ1: Publication Trends	Scopus metadata (year)	Descriptive analysis and trend analysis	Annual publication trend	Evolution of TPACK as a research domain
RQ2:Contributors (Countries, Authors, Journals)	Author affiliations, source titles	Performance analysis	Top contributors	Knowledge production and global diffusion
RQ3: Subject Areas	Scopus subject categories	Descriptive classification	Subject distribution	Disciplinary spread of TPACK
RQ4: Influential Documents	Citation counts	Citation analysis	Top-cited publications	Intellectual influence and knowledge base
RQ5: Conceptual Relationships	Author keywords	Co-occurrence analysis (VOSviewer)	Keyword network map	Intellectual structure and thematic clusters

2.1 Search Strategy

The search strategy was performed to get the aimed literature, conducted using the Scopus database (Elsevier) via the advanced search interface on 15 November 2025 (10:20 GMT+8). The strategic search string was applied to the TITLE-ABS-KEY fields using the following query: TITLE-ABS-KEY ("TPACK" OR "technological pedagogical content knowledge" OR "technological pedagogical and content knowledge") AND TITLE-ABS-KEY ("higher education" OR "university" OR "tertiary education" OR "postsecondary" OR "college instructor*" OR "university lecturer*") AND PUBYEAR > 2005 AND PUBYEAR < 2026.

This search resulted 976 records. All retrieved records were exported from Scopus into CSV format to ensure compatibility with descriptive analysis and bibliometric mapping. The exported metadata included: document title, authors, year of publication, author affiliations, source title, abstract, author keywords, subject areas, and bibliographic references. The exported files were saved as TPACK_HE_Scopus_2006–2025_15nov2025.csv. Two duplicate records were identified using Scopus document identifiers (EID and DOI) and removed from the list. Further, screening, eligibility and inclusion steps were justified and in Table 2, explaining the exclusion of non-relevant records. The DOI list for each included document is supplied as supplementary material. The screening process was conducted by a pair researcher, independently using predefined inclusion and exclusion criteria, ensures that bibliometric metadata selection is objective, reproducible, and accurate. A subset of records (10%)

was rechecked after initial screening to verify accuracy. Then, any ambiguous cases were reviewed and discussed carefully to resolve any disagreement and confirm their relevance to the study contexts.

Table 2. Selection Process

Stage	Number of Records	Description
Records identified through Scopus search	976	Initial retrieval using search query
Records after duplicates removed	974	2 duplicate records removed
Records screened (title & abstract)	974	Eligibility screening conducted
Records excluded (based on exclusion criteria): Non-English publications Not relevant to higher education (e.g., school-level or non-educational domain)	 124 151	 Language restriction applied Context-based exclusion
Final included studies	699	Studies retained for analysis

2.2 Eligibility Criteria for Higher Education and English Language

To ensure consistency in data selection for this study, "higher education" was defined operationally by combining the keyword-based flittering and manual screening. Spcifically, the search query included terms such as "higher education," "university," "tertiary education," "postsecondary," "college instructor," and "university lecturer" within the title, abstract, and keyword fields in Scopus. These terms were used to capture studies explicitly situated within tertiary education contexts. However, due to the teaching environment context, some secondary level documents appeared. Therefore, manual screening has been conducted to all retrieved records to confirm their relevance with the anticipated scope. Studies focusing exclusively on primary or secondary school contexts, teacher education programmes without clear links to university-level instruction, or non-formal education environments were excluded. For ambiguous cases (e.g., studies involving both school and university participants), inclusion was determined based on whether higher education constituted the primary research context. Further, no restriction based on Scopus subject area classification was applied, as TPACK research spans multiple disciplines. This combined approach ensured both systematic retrieval and contextual relevance of the final dataset.

The analysis was limited to documents indexed in the Scopus database and written in English. The English-language filteration was applied to ensure consistency in keyword clarification and analytical accuracy. Stability and solidity of Scopus metadata with English language focus stands the bibliometric review technique to be more realistic and accurate. Besides, Scopus was selected due to its broad multidisciplinary coverage and standardized indexing of citation metadata, which supports reliable bibliometric analysis. Scopus comprehensive coverage of peer-reviewed journals and its extensive indexing of educational technology and higher education research also supplemented the objectives of the study.

2.3 Vosviewer settings

The keyword co-occurrence analysis was conducted using VOSviewer (version 1.6.20). Full counting was applied, whereby each co-occurrence of keywords was counted equally across publications. This approach was selected as it allows for a more direct representation of the frequency and strength of relationships between keywords, which is appropriate for identifying dominant themes within the dataset.

The analysis used a minimum occurrence threshold of 5 for keyword inclusion, ensuring that only sufficiently frequent and relevant terms were visualized. The normalization of the co-occurrence network was performed using the association strength method, as implemented by default in

VOSviewer. Clustering was generated using the software's built-in modularity-based algorithm with a resolution parameter set to 1.00. No minimum cluster size restriction was imposed, allowing the natural structure of the network to emerge. To assess the robustness of the network structure, a sensitivity analysis was conducted by testing a lower occurrence threshold (minimum = 3) and applying fractional counting. The resulting network demonstrated comparable cluster structures and keyword relationships, indicating that the findings are stable across different parameter configurations.

To improve the consistency and accuracy of keyword co-occurrence analysis, a keyword normalization process was conducted. This involved merging synonymous terms, standardizing variations in spelling (e.g., "TPCK" to "TPACK"), and grouping related concepts under common labels (e.g., "e-learning" and "synchronous online classrooms" under "online learning"). The keyword cleaning and normalization dictionary is provided in the supplementary file.

2.4 Citation Analysis

Citation analysis was based on raw citation counts as indexed by Scopus on 15 November 2025. With regards to the identification of influential publications, only documents with 100 or more citations were included in the highly cited document analysis. Self-citations were not excluded, as the analysis aimed to capture overall scholarly influence within the field.

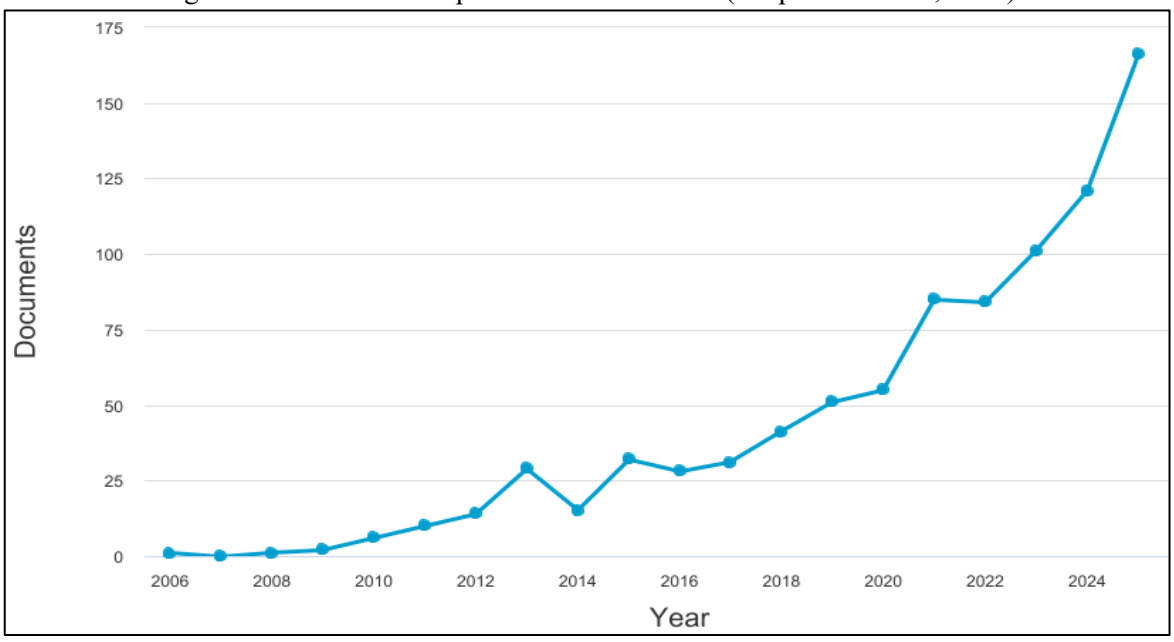
3. Findings

A total of 699 publications were reviewed by the researcher to be analyzed using Scopus descriptive analysis and VOS viewer for mapping the co-occurrence of keywords.

3.1 Publication Output by Year

The publication output retrieved from the Scopus database is shown below:

Figure 1. Publication Output from 2008 to 2025 (Scopus Database, 2025)



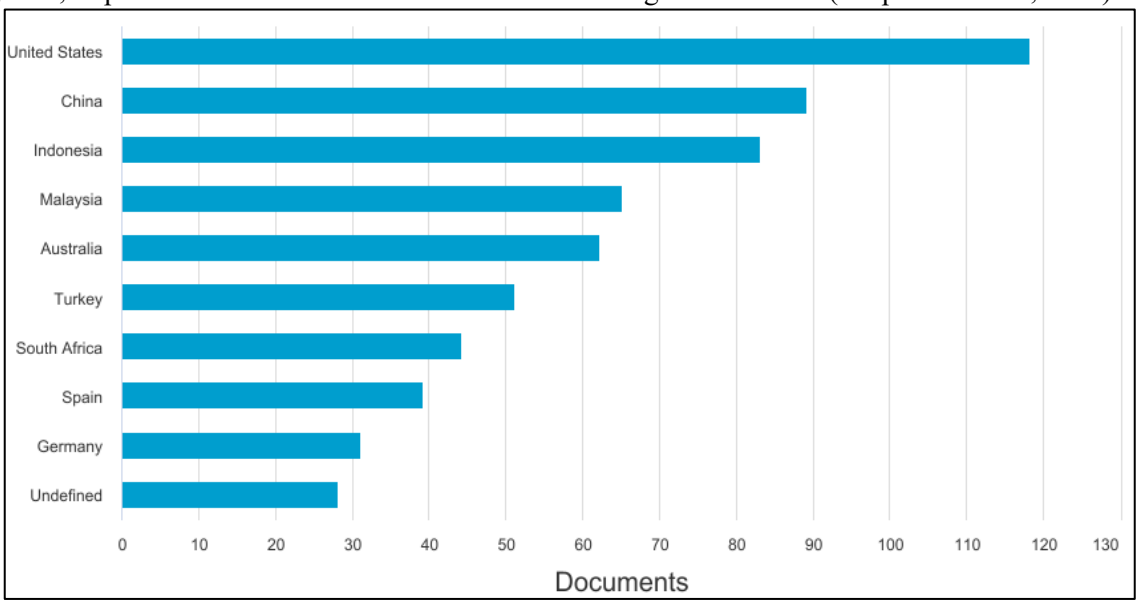
The annual publication trend shows a gradual increase (Figure 1) in TPACK-related studies in higher education from 2008 to 2025, configured from a total of 699 documents. In the early period (2008–2011), only few (less than 30) documents were published, followed by a small growth beginning around 2012. After a small peak in 2013 and a drop in 2014, the number of publications continued to grow

steadily. A more obvious increase appears from 2018 onward, with publication counts rising each year and reaching their highest levels between 2023 and 2025 with more than 100 documents each. Overall, the data indicates a consistent upward trend in publication output across the 18-year period.

3.2 Publication Documents by Country

The analysis shows that publication activity is led by a small group of highly productive countries (Figure 2). The United States records the highest number of documents, followed by China and Indonesia, indicating strong TPACK research engagement in these regions.

Figure 2, Top 10 Countries of TPACK Research Within Higher Education (Scopus database, 2025)

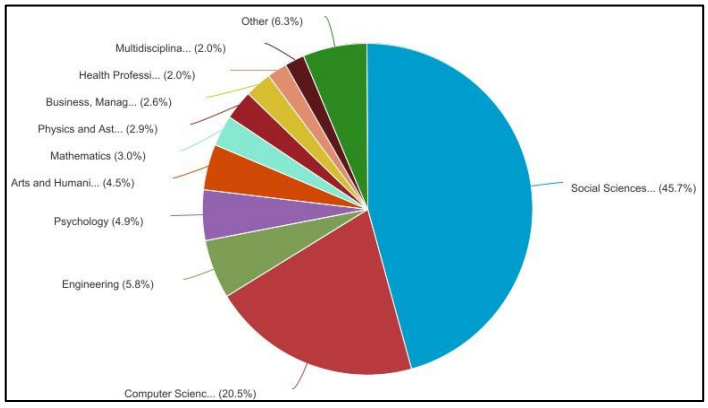


Other countries such as Australia, Malaysia, Turkey, and South Africa also contribute an extensive volume of publications. European countries including Germany and Spain appear in the average, while the Philippines records the lowest output among the top contributing nations. Overall, the distribution implies that research in this area is concentrated mainly in North America and Asia, with contributions from selected regions in Europe, Africa, and Southeast Asia.

3.3 Documents by Subject Area

The distribution of published documents based on subject area is shown in the Figure 3.

Figure 3. The Top 10 Subject Areas for Publication of TPACK Research within Higher Education Context Over the Last Two Decades (Scopus Database, 2025)



The distribution of subject-area (Figure 4) indicates that research on TPACK in higher education is predominantly anchored within the Social Sciences (45.7%), which account for almost half of all publications in the dataset. This reflects the strong positioning of TPACK within fields related to education, teaching, and learning research. Computer Science (21%) forms the second-largest group, highlighting the framework's close alignment with technology integration, digital systems, and instructional technology development. Other contributions emerge from Engineering (6.4%) and Psychology (5.3%), suggesting interest from disciplines concerned with technical, user behaviour, and cognitive aspects of technology-supported learning. Arts and Humanities (4%), as well as Business and Management (2.3%), also appear as meaningful contributors, indicating that TPACK has been applied in diverse instructional contexts beyond traditional teacher education. Smaller yet notable proportions of studies derive from Mathematics, Health Professions, Physics, and Multidisciplinary subject areas, demonstrating that the framework has gradually extended into domain-specific teaching practices. Overall, these patterns show that while the topic remains rooted primarily in social science and technology-related studies, it has attracted growing attention across a range of complementary academic fields.

3.4 Documents per Year by Source

Next, the subsequent bibliometric analysis is the top 5 source of TPACK research publications, shown in Figure 4:

Figure 4. The Top 5 Sources of TPACK Research Within Higher Education Context (Scopus database, 2025)

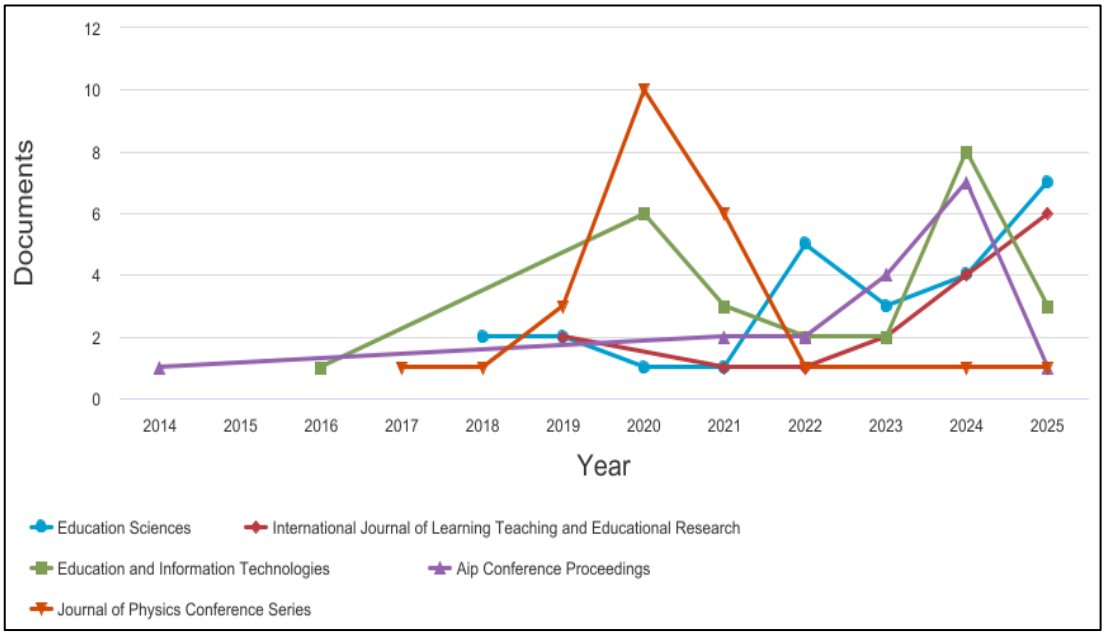


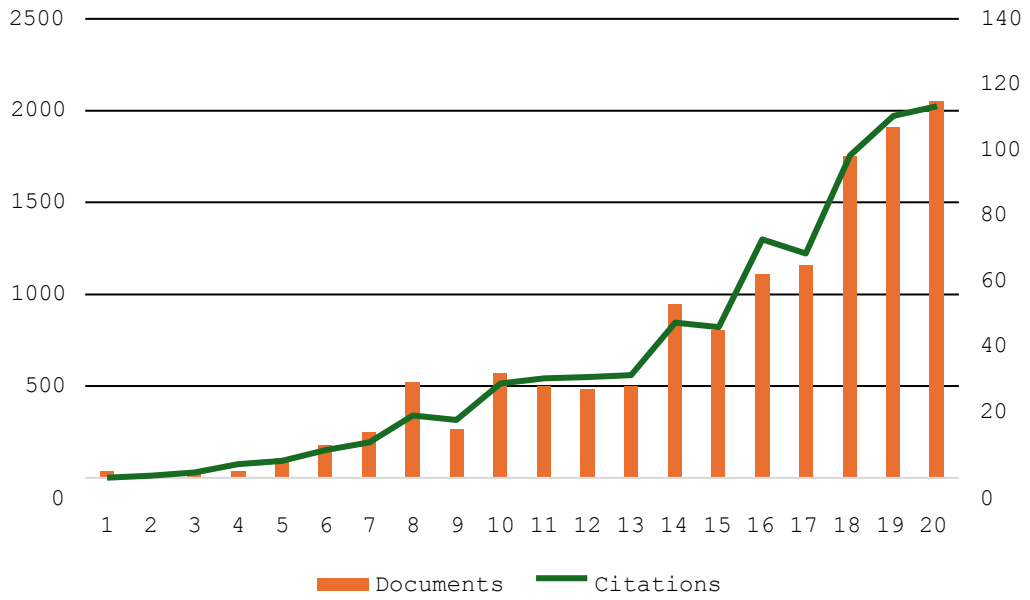
Figure 4 presents the distribution of publications across the most active journals over time. *Education and Information Technologies* showed the strongest and most consistent growth, beginning with a single publication in 2016 and increasing to a peak of eight documents in 2024. *Education Sciences* also demonstrated rising contributions, with noticeable peaks in 2022 and 2025. *Cogent Education* exhibited moderate but steady output, generally contributing between one and six documents annually. Conference-based sources such as the *AIP Conference Proceedings* displayed occasional publication patterns, with notable activity in 2021–2024 but reduced output in 2025. *Journal of Physics Conference Series* demonstrated spiked in 2020 with 10 documents but drop significantly two years after. Overall, the trend indicates that while a few core journals drive most of the TPACK publications, contributions

are subtle across both journals and conference proceedings, reflecting the framework's relevance to multiple academic communities within higher education.

3.5 Citations Output

The following bibliometric analysis discovers the citations output for TPACK research publications in higher education context:

Figure 5. Citation Trends for TPACK Research Publications (Scopus database, 2025)



The analysis of publication and citation trends recorded from 2011 to 2025 shows a clear upward trajectory in TPACK-related research within higher education. As illustrated in Figure 5, the number of documents increased gradually in the early years, with less than 10 publications annually between 2011 and 2015. A steady rise began in 2016, reaching 29 documents in 2018. The growth became more pronounced from 2020 (41 documents) onwards, aligning with global digital transformation in higher education. Publication output in 2025 pointed out with 108 documents, marking the highest annual contribution within the dataset. Citations followed a similar upward pattern, increasing slowly in the early years and then accelerating significantly from 2018 onward, reaching approximately 2,250 citations in 2025. To substantiate the observed growth trend, the compound annual growth rate (CAGR) was calculated for the period 2018–2025. The annual growth rate for the citation documents growth within five years between 2018 (39) to 2025 (112) is 23.47 percent, representing sustainable growth of TPACK research citations (Figure 5) during this period. This parallel increase suggests not only expansion in research output but also sustained scholarly influence and visibility of TPACK studies over time.

Next, we continue analyzing the most cited articles of TPACK research to see research interests, agendas and scopes that received attention from scholars toward TPACK. Only articles with more than 100 citations included in this list, while the remaining publications in the dataset were excluded as they received fewer than 100 citations. The list (16 documents) of highly cited documents (Table 3) was manually verified to ensure metadata accuracy. Records with similar titles were cross-checked using DOIs, author information, and source details to confirm that each entry represented a distinct publication. Minor discrepancies from Scopus interface rankings occur due to database update timing and duplicate documents were then verified. Thus, the rank orders for the most cited articles have been authenticated with the exported CSV format metadata.

Table 3. Documents with more than 100 citations

No.	Document title	Source	Author(s)	Citation
1.	Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and Technology Acceptance Model	Educational Technology and Society	Joo, YJ; Park, S; Lim, E	413
2.	Profiling teachers' readiness for online teaching and learning in higher education: Who's ready?	Computers in Human Behavior	Scherer, R; Siddiq, F; Howard, SK; Tondeur, J.	350
3.	Teacher Educators' Use of Digital Tools and Needs for Digital Competence in Higher Education	Journal of Digital Learning in Teacher Education	Amhag, L; Hellström, L; Stigmar, M.	271
4.	The effects of online professional development on higher education teachers' beliefs and intentions towards learning facilitation and technology	Teaching and Teacher Education	Rienties, B; Brouwer, N; Lygo-Baker, S	218
5.	Preparing preservice teachers for self-regulated learning in the context of technological pedagogical content knowledge	Learning and Instruction	Kramarski, B; Michalsky, T	181
6.	Using digital technology to promote higher education learning: The importance of different learning activities and their relations to learning outcomes	Journal of Research on Technology in Education	Wekerle, C; Daumiller, M; Kollar, I.	144
7.	Using TPACK as a framework to understand teacher candidates' technology integration decisions	Journal of Computer Assisted Learning	Graham, CR; Borup, J; Smith, NB	143
8.	Investigating the impact of teacher education strategies on preservice teachers' TPACK	British Journal of Educational Technology	Baran, E.; Canbazoglu Bilici, S; Albayrak Sari, A; Tondeur, J	136
9.	Learning to teach online: Measuring the influence of faculty development training on teaching effectiveness through a TPACK lens	Internet and Higher Education	Brinkley-Etzkorn, KE	133
10.	Investigating pre-service teachers' acceptance of Web 2.0 technologies in their future teaching: a Chinese perspective	Interactive Learning Environments	Teo, T; Sang, G; Mei, B; Hoi, CKW	126
11.	Educating online student teachers to master professional digital competence: The TPACK-framework goes online	Computers and Education	Tømte, C; Enochsson, AB; Buskqvist, U; Kårstein, A	125
12.	Mitigating the COVID-19 pandemic: a snapshot from Malaysia into the coping strategies for pre-service teachers' education	Journal of Education for Teaching	Mohamad Nasri, N; Husnin, H; Mahmud, SND; Halim, L	124
13.	Technology Integration in Higher Education During COVID-19: An Assessment of Online Teaching Competencies Through Technological Pedagogical Content Knowledge Model	Frontiers in Psychology	Akram, H; Yingxiu, Y; Al-Adwan, AS; Alkhalifah, A	111
14.	Preservice Teachers and Self-Assessing Digital Competence	Journal of Educational Computing Research	Maderick, J.A.; Zhang, S.; Hartley, K.; Marchand, G.	104

15.	The role of TPACK in affecting pre-service language teachers' ICT integration during teaching practices: Indonesian context	Education and Information Technologies	Habibi, A; Yusop, FD; Razak, RA	103
16.	Developing technological pedagogical content knowledge in pre-service mathematics teachers through collaborative design	Australasian Journal of Educational Technology	Agyei, DD; Voogt, J	101

*Citation counts as of November 15, 2025

The citation analysis identified most influential publications that received more than 100 citations within the TPACK and higher education research landscape. The most cited article was authored by Joo, Park, and Lim on pre-service teachers' intention to use technology (413 citations), followed by Scherer et al.'s study on online teaching readiness in higher education (350 citations). Other highly cited works reported on higher education teachers' digital competence needs (271 citations), the effects of online professional development (218 citations), and preservice teachers' self-regulated learning within a TPACK framework (181 citations). Additional publications addressed technology integration decisions, online teaching effectiveness, and faculty development (143–133 citations). The remaining article with citation counts between 101 and 126, focused on TPACK development strategies, pre-service teachers' acceptance of digital technologies, and the role of TPACK in subject-specific teaching such as language and mathematics. Overall, these highly cited studies largely concentrate on pre-service teacher preparation, digital competence, professional development, and technology integration in higher education contexts.

To complement total citation counts, citation impact was normalized using citations per year to account for differences in publication age. The researcher extracted the top 20 citations per year as presented in Table 4. The results indicate that several recent publications rank highly when adjusted for publication year. For example, studies by Wekerle, Akram and Yang demonstrate the higher annual citation impact compared to earlier publication documents. This suggests that while earlier studies dominate cumulative citation counts, more recent research has gained rapid scholarly attention, particularly in areas related to online learning, digital competence, and post-pandemic teaching practices. The inclusion of normalized citation metrics therefore provides a more balanced understanding of both established and emerging influential works in the field.

Table 4. Top 20 TPACK publications in higher education ranked by citations per year

Author (First)	Year	Citations	Citations/Year
Joo, Y.J.	2018	413	51.6
Scherer, R.	2019	350	50.0
Amhag, L.	2019	271	38.7
Wekerle, C.	2022	144	36.0
Akram, H.	2021	111	22.2
Mohamad Nasri, N.	2020	124	20.7
Baran, E.	2019	136	19.4
Habibi et al.	2020	103	17.2
Brinkley-Etzkorn, K.	2018	137	17.1
Rienties et al.	2013	218	16.8
Mpungose	2020	96	16.0
Teo, T.	2018	126	15.8
Yang et al.	2025	144	14
Tømte et al.	2015	125	11.4
Kramarski, B.	2010	181	11.3
Madriaga et al.	2016	104	10.4
Graham et al.	2012	143	10.2
Herring	2016	90	9.0

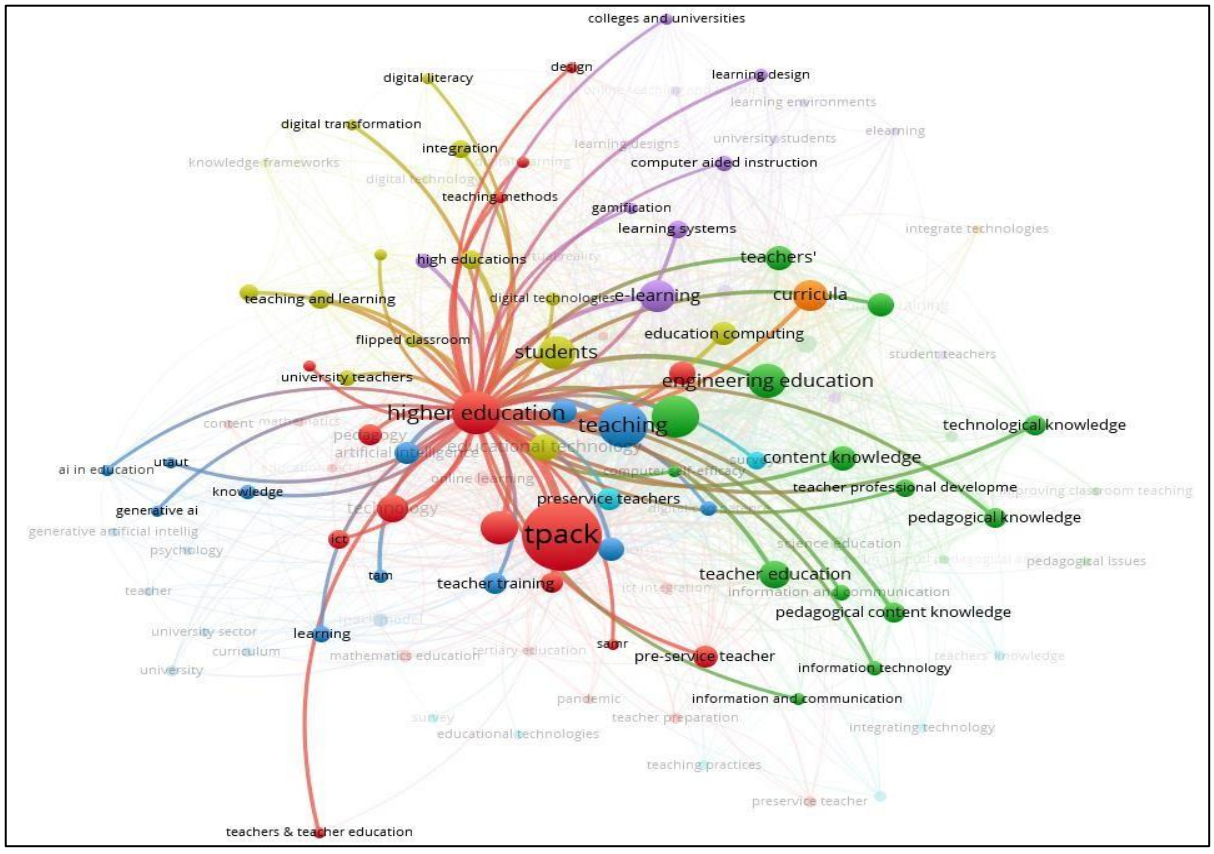
Benson et al.	2013	97	7.5
Agyei & Voogt	2012	101	7.2

From a theoretical perspective, this shift may signal a transition from foundational TPACK conceptualisation toward more applied and context-sensitive research. The emergence of high-impact recent studies suggests that TPACK is being actively reinterpreted and extended to address contemporary educational challenges (Doğru et al., 2020). This reinforces the need for continued research that bridges theoretical development with practical implementation in higher education contexts.

3.6 Keyword Co-Occurrence Network

The analysis for keyword co-occurrence network was conducted using VOSviewer. The keyword co-occurrence analysis generated using VOSviewer (Figure 6) reveals the structure of TPACK research conceptually within higher education. The network shows TPACK as the most dominant and central point, indicating its role as the core construct around which related research themes are clustered. Strong co-occurrence links connect TPACK with terms such as teacher education, pre-service teachers, technological knowledge, pedagogical knowledge, and content knowledge, reflecting the framework's theoretical foundation and its continued emphasis on teacher knowledge domains.

Figure 6. Keyword Co-occurrence for TPACK Research (VOSviewer, 2025)



From an analytical perspective, the keyword co-occurrence network generated using VOSviewer comprised 131 nodes with high number of links (2,285) and total link strength (5,775), resulting in an average degree of approximately 34.9, indicating that each keyword is, on average, connected to a substantial number of other keywords. The network density was estimated at 0.27, suggesting a moderately dense and well-connected conceptual structure.

This indicates that TPACK research in higher education has evolved into a densely connected knowledge domain with strong conceptual integration. Rather than forming isolated thematic silos, the network demonstrates substantial overlap across clusters, suggesting that research topics such as digital competence, online learning, and instructional design are increasingly interconnected. These metrics indicate that TPACK research in higher education exhibits a high level of conceptual integration, with strong interconnections among key themes. Central nodes such as "TPACK," "technology integration," and "higher education," play a significant role in connecting multiple thematic clusters within the network. While modularity and advanced centrality measures were not explicitly calculated, the clustering structure generated by VOSviewer and the observed link patterns provide sufficient evidence of the network's thematic organization and intellectual cohesion.

The presence of 60 clusters further reflects the diversification of the field, where emerging topics and niche areas coexist alongside core themes. This pattern may indicate a transition from a relatively unified theoretical framework toward a more pluralistic and interdisciplinary research landscape. However, the continued centrality of core constructs such as TPACK suggests that the field remains anchored in its foundational framework, supporting a cumulative rather than fragmented development trajectory.

The visualization also shows a complex network connecting TPACK with higher education, forming a major thematic cluster (red). At the node level, the keyword "higher education" demonstrated 48 links with a total link strength of 147, indicating that it is moderately well-connected within the network. This suggests that while higher education serves as an important contextual anchor for literature, it is not the dominant conceptual driver of the network. Instead, it functions as a bridge term that links TPACK with various thematic areas such as teaching practices, digital competence, and technology integration. The strong links between higher education, students, and e-learning also highlight the framework's application in studies exploring online, blended, and digitally supported learning environments.

A second major cluster (green) connects TPACK to curricula, engineering education, content knowledge, and teacher professional development, suggesting wider disciplinary applications outside teacher preparation programs. In the meantime, new themes such as artificial intelligence, generative AI, digital transformation, and learning design appear less connection but growing (blue and yellow clusters). This shows that TPACK study is starting to look more at new advance digital technologies.

Overall, the VOSviewer network structure proves that TPACK research in higher education is well-established and increasingly expanded. It also reveals the transforming environment for technology integration in higher education as the research areas on AI-enhanced learning, digital literacy, and curriculum innovation are gaining importance and emerging.

4. Discussion

4.1 Interpretation and comparison with prior reviews

The two-decade time frame (2006–2025) provides an important lens for interpreting the evolution of TPACK research in higher education. Since the framework was introduced by Mishra & Koehler (2006), the observed increase in publication output reflects its gradual transition from a conceptual model to a widely applied framework in digitally mediated teaching contexts. The sustained growth, particularly after 2018, can be linked to broader structural shifts in higher education, including increased institutional investment in digital learning infrastructure, expansion of online and blended learning programmes, and policy-driven digital transformation agendas (Kallou & Kikilia, 2021; Menon & Suresh, 2022).

The increase in publications after 2020 is likely associated with the COVID-19 pandemic (Chen & Hsu, 2022), which forced universities globally to rapidly adopt online and hybrid teaching models. This shift intensified the need to understand how educators integrate technology with pedagogy and content, positioning TPACK as a relevant analytical framework. While this study observes a strong growth trend, it should be interpreted cautiously as a correlation rather than a direct causal relationship, as other factors such as increased indexing coverage and publication accessibility may also contribute to this pattern.

In terms of geographical distribution, the dominance of the United States can be attributed to its early contribution to TPACK's conceptual development and its well-established research infrastructure in educational technology. The strong representation of China reflects national-level investments in digital education and large-scale higher-education expansion (Knox, 2020). Meanwhile, the prominence of Indonesia suggests increasing regional engagement with technology-enhanced teaching, possibly driven by national digitalisation initiatives and growing emphasis on higher-education reform (Aditya et al., 2020; Novianti & Nurlaelawati, 2019; Sofwan et al., 2021). These patterns indicate that TPACK research is influenced not only by theoretical interest but also by policy, funding priorities, and institutional capacity.

Compared with earlier reviews that focused primarily on school education (Shabira et al., 2024) or general contexts (Suprapto et al., 2021; Zou et al., 2022), this study highlights that TPACK research in higher education is both expanding and diversifying. However, the moderate connectivity of higher education as a keyword within the network suggests that the field remains conceptually anchored in general TPACK constructs, with limited theoretical differentiation specific to tertiary education contexts. This indicates a need for more context-sensitive research that explicitly addresses the unique pedagogical and institutional characteristics of higher education.

4.2 Practical Implications for Higher-Education Policy and Teacher Education

The findings of this review offer several practical implications for higher-education policy and academic development. First, universities should implement structured, institution-wide professional development programmes grounded in TPACK rather than relying on isolated or short-term training initiatives. Academic development units may prioritise blended TPACK training workshops tailored to disciplinary needs (e.g., STEM vs humanities), establish cross-faculty communities of practice, and incorporate pre- and post-assessment of TPACK using validated instruments to evaluate training effectiveness. Structured, sustained support rather than short-term workshops can better support educators in integrating technology meaningfully into pedagogy and content. Maipita et al. (2023) suggested that support from the institution is valuable for TPACK competency that will lead to high teachers' performance. Moreover, in today's digital world, university teachers are also required to have creative and innovative ways of working (Shafait & Huang, 2023) to improve their students' performance.

Second, teacher education and academic development programmes should embed TPACK-oriented competencies within curriculum design, assessment strategies, and teaching practice. This is particularly important in higher education, where many academics enter the profession without formal pedagogical training. Institutions may implement mentoring schemes, peer-observation frameworks, and collaborative course design initiatives to support educators in applying TPACK within authentic teaching contexts. Embedding TPACK within academic development programmes can therefore strengthen educators' confidence and competence in implementing technology-enhanced teaching strategies in sustainable ways.

Third, at the institutional level, universities should align digital teaching competence with performance evaluation and promotion systems. Recognising innovative teaching practices through promotion criteria, teaching awards, and workload allocation can incentivise sustained pedagogical innovation.

Additionally, institutional support mechanisms, including access to digital tools, instructional design support, and funding for teaching innovation should be systematically integrated into academic development strategies.

Collectively, these measures can support a more sustainable and contextually relevant integration of TPACK in higher education, moving beyond individual competence toward institutional transformation.

4.3 Future Research

Based on the identified findings, this review proposes several directions for future research. First, more longitudinal and explanatory studies are needed to examine how TPACK develops over time among higher-education educators. Future studies could address questions such as: *How does sustained institutional support influence the evolution of educators' TPACK across academic career stages?* Longitudinal survey designs or panel studies would be particularly suitable. In higher education, where formal pedagogical training is not usually necessary for academic positions, institutional environments can significantly influence how educators engage with technology-integrated teaching practices. Investigating TPACK development longitudinally across career stages helps determine when and how support mechanisms are most effective. Further determination based on different forms of support are needed for early-career, mid-career, and senior academics can be explored. This kind of research would assist universities design targeted academic development policies that promote continuous pedagogical innovation rather than one-off training interventions. Second, qualitative and design-based research remains underrepresented. In-depth case studies and design-based research could explore *how educators enact TPACK in authentic higher-education contexts*, particularly within digitally intensive disciplines such as tourism, engineering, and health sciences. The genuine beneficial output from various context in higher education might help the university stakeholders improve the curriculum, teaching methods, assessments and program outcomes.

4.4 Limitations

This study has several limitations that should be considered when interpreting the findings. First, the analysis is based solely on the Scopus database, which may introduce coverage bias, as relevant publications indexed in other databases such as Web of Science or Google Scholar were not included. Second, the restriction to English-language publications may exclude important contributions from non-English-speaking regions, potentially underrepresenting global research diversity.

Third, the inclusion of journal articles and conference papers may result in uneven representation across disciplines, as some fields rely more heavily on conference publications than others. Fourth, citation-based analyses are subject to citation-age bias, where older publications have had more time to accumulate citations compared to recent studies. Although citations per year were used to mitigate this issue, some bias may still remain.

Future research could address these limitations by incorporating multiple databases, including multilingual sources, and applying more advanced normalization techniques to further enhance the robustness of bibliometric findings.

5. Conclusion

This bibliometric review provides a comprehensive overview of two decades of TPACK scholarship in higher education, revealing a field that has grown steadily in figures, diversity, and global access since 2006. The analysis shows increasing research productivity, especially from 2018 onward, reflecting the rising importance of digital pedagogy, online learning, and digital applications in today's digital

education environment. Findings also demonstrate that TPACK-related studies are secured primarily within the social sciences but have expanded into STEM, vocational education, psychology, and other discipline domains. High citation works continue to shape the core understanding of teacher readiness, technology acceptance, and professional competence. On the other hand, more recent publications increasingly highlight pedagogical digital competence, innovative teaching behavior, and organizational support, projecting TPACK research to be more integrative with these domains. Overall, the review highlights how TPACK has evolved from a conceptual model to a widely applied framework guiding more empirical research, instructional innovation, and policy discussions across higher education.

6. Data and Code Availability

The dataset used in this study, including the DOI list, keyword normalization dictionary, and VOSviewer input files, is provided as supplementary material.

7. Funding
This research received no external funding.

8. Conflict of Interest
The authors declare no conflict of interest.

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