Mapping the Progress of Technological Pedagogical and Content Knowledge Research: Bibliometric Analysis

Prihantini[1]*, Ai Rukmini[2], Ardhana Januar Mahardhani[3], Ratna Rintaningrum[4]

[1]Kampus Universitas Pendidikan Indonesia at Cibiru, Pendidikan St. No.15, Bandung, West Java, 40626, Indonesia
[2]Institut Nida El Adabi, Bogor, Raya Dago St., Bogor, West Java, 16360, Indonesia
[3]Universitas Muhammadiyah Ponorogo, Budi Utomo St. No.10, Ponorogo, East Java, 63471, Indonesia
[4]Institut Teknologi Sepuluh Nopember, Arief Rahman Hakim St., Surabaya, East Java, 60111, Indonesia
*Corresponding author, email: prihantini@upi.edu

doi: 10.17977/um065.v6.i2.2026.12

Article history
Submitted: 18 January 2026
Revised: 20 February 2026
Accepted: 21 February 2026
Published: 23 February 2026

Keywords
Technological pedagogical content knowledge
Bibliometric analysis
Educational technology
Teacher education
Publication trends

Abstract
This bibliometric analysis maps the progress of Technological Pedagogical Content Knowledge (TPACK) research over the past decade, highlighting its significance in integrating technology into education. Despite its growing relevance, existing literature indicates a concerning lack of collaboration across disciplines and minimal contributions from developing countries. The study employs bibliometric methods to analyze publication trends, identify key authors and institutions, and explore thematic relationships within TPACK research. Findings reveal a significant increase in TPACK publications, particularly peaking in 2022, with a diverse range of topics being addressed, including educational technology, teacher education, and the impact of COVID-19. The analysis also underscores the need for further interdisciplinary research and emphasizes the potential for TPACK to enhance educational practices, especially in the context of modern technological advancements. By providing insights into publication patterns and identifying under-researched areas, this study aims to guide future research efforts and promote a more comprehensive understanding of TPACK's applications in education.

1. Introduction

The rapid advancement of digital technology has significantly transformed various sectors of society, including education. The integration of technology into teaching and learning processes is no longer optional but has become an essential component of educational practice in the digital era. In response to this transformation, the framework of Technological Pedagogical Content Knowledge (TPACK) has emerged as a foundational model for understanding how teachers integrate technology effectively into instruction (Schubatzky et al., 2023). TPACK extends Shulman's (1986) concept of Pedagogical Content Knowledge (PCK) by incorporating technological knowledge as a critical domain, thereby conceptualizing the complex interplay among content, pedagogy, and technology (Schubatzky et al., 2023; Wang et al., 2018).

As digital tools continue to evolve, educators are required not only to master subject content and pedagogical strategies but also to align these competencies with appropriate technological applications. Consequently, TPACK has become a central framework in teacher education, curriculum development, and educational research aimed at fostering effective technology integration (Foulger et al., 2022; Huang & Musah, 2024).

Despite its conceptual strength, implementing TPACK in educational settings remains challenging. Many teachers struggle to consistently integrate digital technology into standards-based instruction (Ozden et al., 2024). Additionally, insufficient institutional support, particularly in the form of structured professional development and teacher training programs grounded in TPACK principles, has limited its effective application (Pessin et al., 2022). These challenges underscore the need to better understand how TPACK research has evolved and how it informs educational practice globally.

Given the rapid expansion of TPACK-related publications over the past decade, there is a pressing need to systematically map and evaluate the intellectual structure and development trends of this field. Bibliometric

ISSN: 2797-3174

analysis offers a robust methodological approach to assess publication patterns, collaboration networks, influential works, and thematic evolution within a research domain (Donthu et al., 2021; Mukherjee et al., 2022). Such analysis can provide comprehensive insights that extend beyond traditional narrative reviews.

Over the last two decades, TPACK research has shown significant growth and diversification. Studies have examined teacher competence, professional development, technological integration models, and subject-specific implementations of TPACK (Tseng et al., 2022). Moreover, recent research has explored interdisciplinary dimensions and the influence of digital transformation on pedagogical innovation (Schmid et al., 2024).

However, the distribution of TPACK research is uneven across geographical contexts. A substantial proportion of studies originate from countries such as China and Australia, while contributions from developing countries remain relatively limited (Huang & Musah, 2024). Furthermore, collaboration across disciplines and international research networks appears to be less intensive than expected for a field that inherently combines technology, pedagogy, and content knowledge (Hieu et al., 2024; Schmid et al., 2024).

Although previous reviews have examined specific aspects of TPACK implementation, fewer studies have provided a comprehensive bibliometric mapping that integrates annual scientific production, collaboration patterns, institutional contributions, citation impact, and thematic evolution within a single analytical framework (Celik, 2023).

Despite the expanding body of TPACK literature, several gaps remain evident. First, limited interdisciplinary and cross-national collaboration may restrict the development of a more holistic understanding of technology integration in diverse educational contexts (Schmid et al., 2024; Tseng et al., 2022). Second, the concentration of research in specific countries suggests an imbalance in global knowledge production, potentially overlooking contextual challenges faced by educators in developing regions (Huang & Musah, 2024).

Moreover, while TPACK research continues to increase quantitatively, there is a lack of comprehensive bibliometric studies that systematically analyze publication trends, intellectual structures, and thematic trajectories across time. Without such mapping, it is difficult to identify emerging research fronts, influential scholars, collaborative networks, and underexplored themes that require further investigation.

In response to these gaps, this study conducts a bibliometric analysis to systematically map the development of TPACK research. Specifically, this study aims to:

a. Analyze annual scientific production to identify publication trends over time.

b. Examine collaboration patterns among authors, institutions, and countries.

c. Identify the most influential authors, institutions, sources, and highly cited documents.

d. Explore the intellectual and thematic structure of TPACK research through thematic mapping and three-field analysis.

By providing a comprehensive bibliometric overview, this study contributes to a deeper understanding of the evolution, dynamics, and global distribution of TPACK scholarship. The findings are expected to inform researchers, educators, and policymakers by highlighting under-researched areas, strengthening international collaboration, and guiding future research directions in technology-integrated education (Donthu et al., 2021; Mukherjee et al., 2022).

2. Method

This study employed a bibliometric analysis to systematically map the intellectual structure, collaboration patterns, and thematic evolution of research on Technological Pedagogical Content Knowledge (TPACK). Bibliometric analysis is recognized as a robust quantitative approach for synthesizing large bodies of literature, identifying research trends, and revealing knowledge structures within a specific field (Donthu et al., 2021; Mukherjee et al., 2022). Beyond descriptive statistics, this study integrates analytical interpretation to explain how collaboration networks and thematic shifts reflect the maturation and diversification of TPACK scholarship.

2.1. Data Source and Justification

The data were retrieved from the Dimensions database. Dimensions was selected for several methodological and practical reasons. First, it provides broad multidisciplinary coverage, including education, social sciences, and technology studies, which are central to TPACK research. Second, compared to more

ISSN: 2797-3174

restrictive indexing platforms, Dimensions includes a wider range of peer-reviewed journal articles, enabling a more comprehensive representation of global scholarship. Third, it offers integrated citation data and metadata suitable for advanced bibliometric analysis, including co-authorship, co-citation, and keyword co-occurrence mapping.

The choice of Dimensions also aligns with recent bibliometric studies in education and social sciences that highlight its capacity to capture emerging and regionally diverse publications, particularly from developing countries that may be underrepresented in other databases.

2.2. Data Collection Techniques

Article metadata was obtained from the Dimensions Database to accumulate publications regarding TPACK. TPACK data was taken for the last ten years from 2014 to 2024. The term or keyword for the search uses the word "TPACK". The collected TPACK article data was then filtered based on the year of publication, document type, field of study, and document source. The results of the data retrieval filter from "dimensions" are shown in Figure 1.

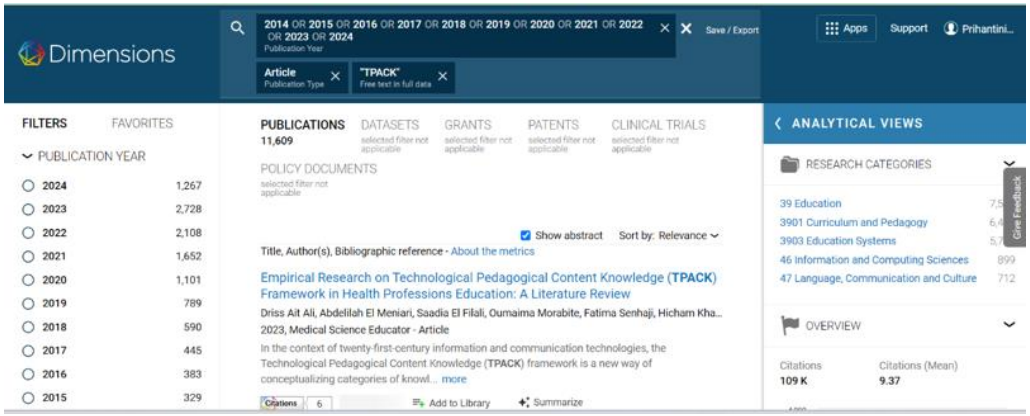

Figure 1. The Process of Capturing and Filtering Data is Sourced from Dimensions

The next step was based on the keywords found; the metadata from the dimensions was downloaded using the summative value (.csv) format.

2.3. Search Strategy

Data collection was conducted on **[insert exact retrieval date, e.g., 15 January 2026]** to ensure transparency and replicability. The full search string used in the Dimensions database was: ("Technological Pedagogical Content Knowledge" OR "TPACK" OR "TPCK") AND (education OR teaching OR learning) The search was applied to the **title and abstract fields** to ensure relevance and conceptual alignment with the TPACK framework. No restrictions were initially placed on publication year in order to capture the full historical development of the field.

2.4. Inclusion and Exclusion Criteria

To ensure methodological rigor, explicit inclusion and exclusion criteria were applied:

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Peer-reviewed journal articles.	Conference proceedings, book chapters, dissertations, editorials, and review notes.
Publications explicitly addressing TPACK or TPCK as a conceptual or analytical framework.	Articles not centrally focused on TPACK (e.g., mentioning TPACK only peripherally).
Articles published in English.	Duplicate records.
Articles with complete bibliographic metadata (author, year, source, affiliation, keywords, citation data).	Publications with incomplete metadata or missing citation information.

After applying these criteria, the final dataset consisted of final number documents used for analysis.

2.4.1. Data Coding And Analysis

Coding and data analysis were done by analyzing the metadata obtained from the dimensions using R Studio software with the bibliometric package, installing the bibliometric package, and applying the code

ISSN: 2797-3174

"install. packages (bibliometric)" which must be done first, calling the code "library (bibliometrics)", followed by the code "biblioshiny" to open the bibliometric analysis program in the browser window, and importing the metadata dimensions in the "Load Data" section. With this analysis step, a visualization code will appear, including the main information of the article, the trend of article development every year (annual scientific production), the relationship between data (three-field rent), relevant sources, relevant authors, institutions that have many documents (relevant affiliation), documents that are widely cited, and the development of research themes (thematic map). The result of this step-by-step is a descriptive analysis to interpret the findings.

The bibliometric analysis was conducted using bibliometric mapping techniques that included:

a. Annual scientific production analysis to identify publication growth trends and phases of development.

b. Co-authorship analysis to examine collaboration patterns among authors, institutions, and countries.

c. Citation and co-citation analysis to determine influential authors, sources, and foundational works shaping the intellectual structure of TPACK.

d. Three-field plot analysis to explore relationships among authors, keywords, and sources.

e. Keyword co-occurrence and thematic mapping to identify dominant themes and their evolution over time.

Rather than merely reporting frequency counts, this study interprets these indicators analytically. For example, collaboration networks were examined to determine whether TPACK research is dominated by localized research clusters or characterized by strong international partnerships. Dense inter-country collaboration suggests intellectual integration and global diffusion of TPACK, whereas fragmented clusters may indicate regional specialization or conceptual divergence.

Similarly, thematic evolution analysis was conducted to track shifts in research focus. Early TPACK studies primarily emphasized conceptual validation and teacher knowledge measurement. Over time, themes expanded toward digital competence, STEM integration, online learning environments, and teacher professional development. This thematic diversification indicates the maturation of TPACK from a conceptual framework into an applied research paradigm addressing emerging technological contexts. By combining structural mapping with interpretive analysis, this method enables a deeper understanding of how TPACK scholarship has evolved intellectually, geographically, and thematically.

2.5. Reliability and Transparency

To enhance transparency and replicability, all search parameters, criteria, and analytical procedures were documented systematically. The fixed data retrieval date ensures that the dataset represents a clearly bounded snapshot of TPACK scholarship at a specific time point, acknowledging that bibliometric indicators may evolve as new publications emerge.

3. Results and Discussion

3.1. Results

3.1.1. Main Information

The results of the analysis by exporting metadata to the bibliometrics, show the initial display of the software containing the main information about the document to be analyzed using bibliometrics. Figure 2 shows that metadata about TPACK totaled 500 documents published over the last 10 years, from 2014 to 2024. This data is the object of bibliometrics analysis. The documents are sourced from 153 journals, with an average annual growth of 45.32%. A total of 1559 authors were identified, of whom 63 were single authors. International writing collaboration reached 22.4% with a writing contribution of 3.5 per document, and there were 281 keywords.

ISSN: 2797-3174

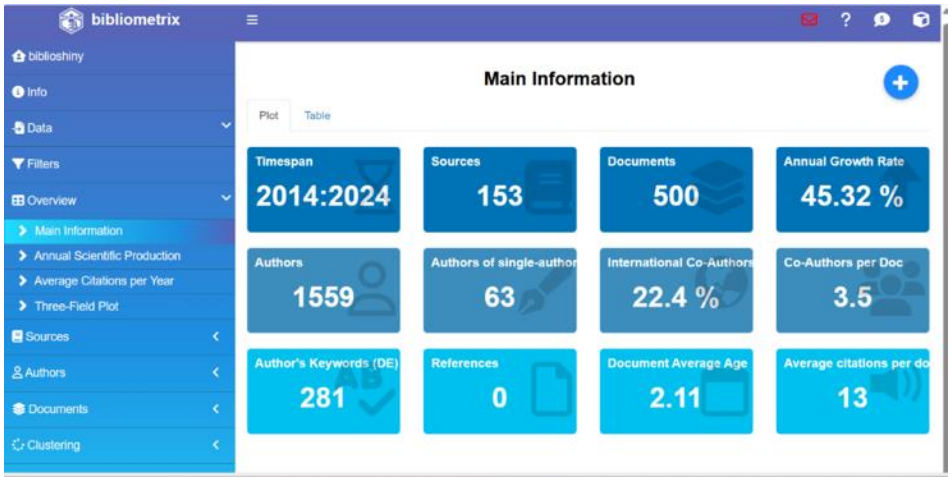

Figure 2. Main Information

3.1.2. Article Evolution Trends Every Year

The results of the analysis present TPACK publications annually for the last 10 years, from 2014 to 2024 (Figure 3). Figure 3 shows that the graph of research trends on TPACK over the past 10 years has increased from 2014 but decreased from 2023 to 2024. The peak of publication occurred in 2022, with 190 articles published. This data indicates that research on TPACK remains relevant for exploration in the coming years, as TPACK continues to be important for the development of learning technology.

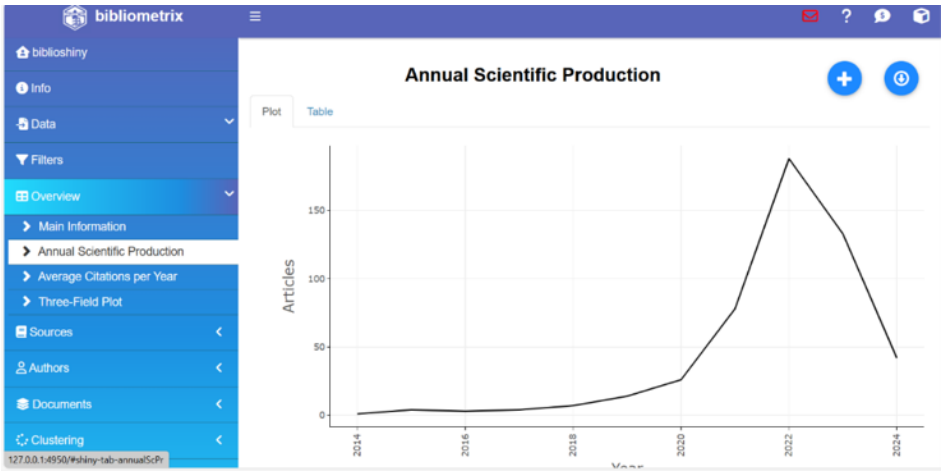

Figure 3. Annual Scientific Production

3.1.3. Data Relationships from Different Countries

The relationship between data from different countries that publish articles on TPACK is seen in the Three-Field Port presented in Figure 4. This analysis provides information on countries that are highly productive and have high attention in researching TPACK. Figure 4 provides data showing that China is a very productive country with high concerns related to TPACK research, followed by Spain, America, Australia, and Malaysia in order. These five countries are countries that have an interest in researching TPACK. Topics related to TPACK can be seen as the most dominant ones, which include topics such as humanity, COVID-19, adults, learning, and pandemics. Other topics were identified but not widely used as research focuses, and some countries were not among the five productive countries that published TPACK articles.

ISSN: 2797-3174

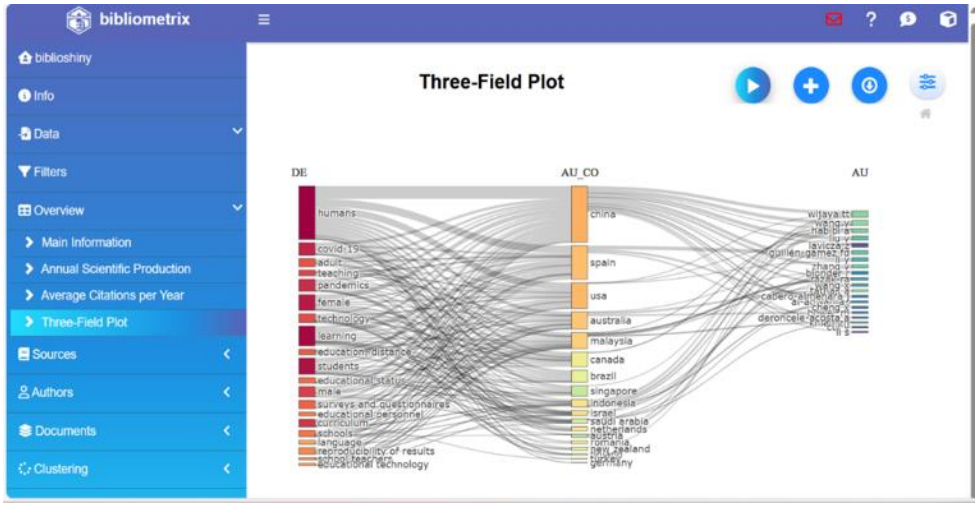

Figure 4. Three-Field Port

3.1.4. Trend Topics

Figure 5 provides information on topic trends integrated with TPACK from 2014 to 2024. Figure 5 shows that the trend of topics over the past 10 years has changed from 2016 to 2024. From 2016 to 2018, TPACK topics related to nurse education were still dominant. The years 2018 to 2020 experienced several trend topics, namely computer-assisted learning, educational technology, and teaching, but the topic of computer-assisted learning integrated with TPACK lasted for a long time, from 2018 to 2022. In the period from 2019 to 2022, there has been a development of a widespread trend of topics, namely teaching, gender (male and female), curriculum, students, health, SARS and Covid, universities, and learning. The trend of topics related to students occurred from 2022 to 2023. A very rapid topic trend is the topic of TPACK which is integrated with humanity and is seen to be on top record in 2022. The next development is a trend of topics in education that occur from 2022 to 2024.

Figure 5. Trend Topic

3.1.5. The Most Relevant Sources

Relevant sources used to find out the trends of emerging journals developing and contributing to the research are shown in Figure 6. Figure 6 illustrates the data used to identify the most relevant sources of publications. The most relevant publication source is the journal Frontiers in Psychology, with a total of 80 publications. The next most relevant source is the journal Education and Information Technologies, with a total of 67 publications. The Heliyon Journal has 32 publications, and the International Journal of Environmental Research has 18 publications. Based on the data (Figure 6), the most relevant sources of publications are shown. The focus of the dominant research topics is in the fields of psychology, educational technology, and the environment. Thus, research on TPACK has been widely published in journals that focus on this field.

In addition, Figure 6 also shows that the sources of publications about TPACK are quite diverse, ranging from psychology journals and educational technology to general journals related to technology and learning.

ISSN: 2797-3174

This data demonstrates the existence of collaboration and interdisciplinary approaches in TPACK research and the dynamics of TPACK research.

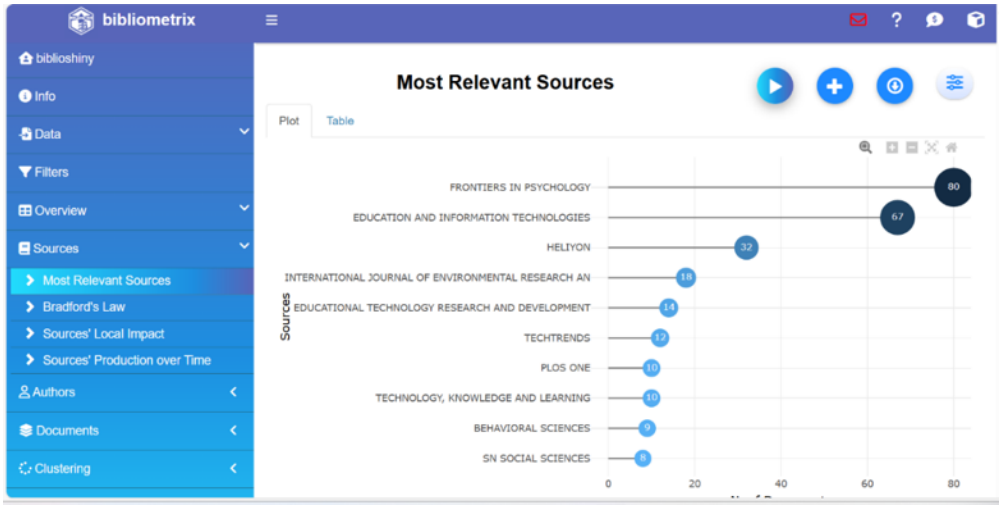

Figure 6. The Most Relevant Sources

3.1.6. The Most Relevant Authors

The most relevant authors can be identified by examining their descriptions. The authors who are most dominant in research publications on TPACK are described in Figure 7. Figure 7 shows that the most dominant author is Tatnall A with a total of 11 publications. It can be said that Tatinall A has made many significant contributions to TPACK research. The author who contributed quite a bit was also Wang Y with 9 publications, followed by Wijaya TT with 7 publications, showing a fairly high involvement in this study. Habibi A and Zhang Y have the same number of publications, namely 6 publications, thus placing both of them as authors who have contributed quite a lot to TPACK research. Guillén-Gámez FD and Liu Y and Li Y each have 5 publications, which also shows consistent involvement in TPACK research. Khalif ZN and Razak RA each have 4 publications, showing sufficient contributions although not as many as other authors.

Overall, this pattern shows a stratification in the level of contribution of authors. There is a very dominant group of writers, followed by a group of writers with moderate or moderate contributions, and some writers with lower contributions. This data reflects the dynamics of TPACK's research, where some authors are leading and dominating, while other groups also participate consistently.

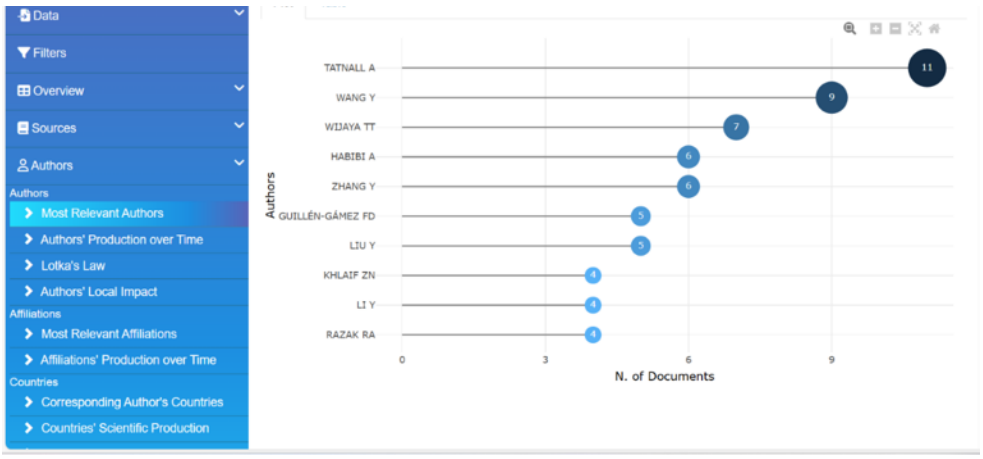

Figure 7. The Most Relevant Authors

3.1.7. The Most Relevant Affiliation

The affiliate information that contributed to the TPACK research are very dominant, moderately dominant, and low-dominant affiliates. All these criteria are shown in Figure 8. Figure 8, provides information on the most dominant affiliation in the TPACK research collaboration. The most dominant affiliation is the Ministry of Education of Malaysia, Putrajaya, with a total of 18 affiliates. It demonstrates a strong collaboration between researchers and Malaysian government institutions in TPACK research. The Department of Science Teaching at the Weizmann Institute of Science, Rehovot, and Victoria University, Melbourne, Australia, each has 11 affiliates.

ISSN: 2797-3174

It also demonstrates the high level of involvement of both institutions in the TPACK research. The Faculty of Medicine at the University of Colombo, Colombo, Sri Lanka, has 10 affiliates, demonstrating the significant contributions of academic institutions in Sri Lanka. Walter Cantídio University Hospital, Federal University, Center of Research, Development, and Innovation in Psychology, and the Faculty each have 9 affiliates; this data also shows the consistent involvement of these institutions. The Department of Mathematics, Faculty of Science and Mathematics, University; the Department of Surgery, Emergency Discipline, "Victor Babes" University; and the Department of Teaching and Educational Organization, University of Suceava, each have 8 affiliates, demonstrating a consistent contribution from these institutions.

Overall, the data pattern seen in Figure 8 shows the extensive involvement of various institutions, including government, academic, and hospital entities, in the TPACK research. It demonstrates a strong interdisciplinary collaboration in the field of TPACK research.

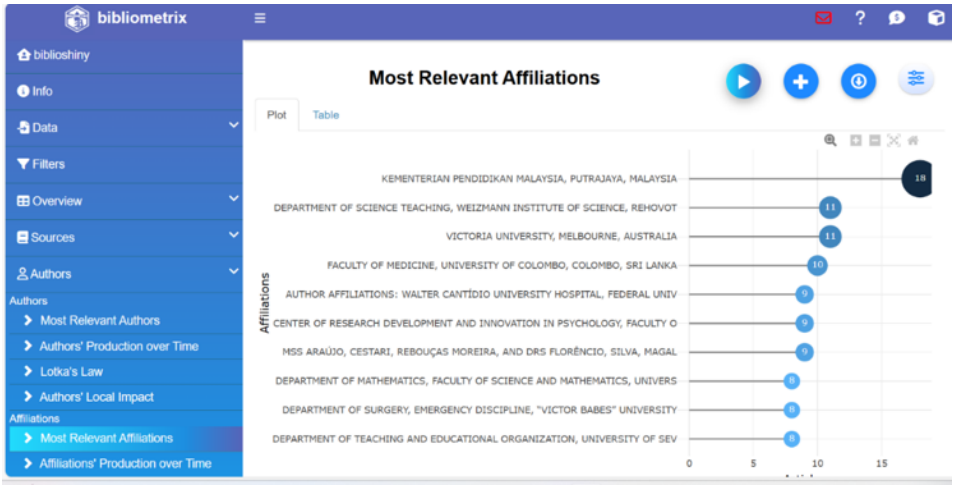

Figure 8. The Most Relevant Affiliation

3.1.8. The Most Global Cited Documents

The most globally cited documents related to TPACK are presented in the most globally cited documents in figure 9. Based on the data presented in Figure 9, it can be identified about 10 Descriptions (Table 1). Based on the title and publication data shown in Figure 9 and Table 1, the dominating document names in this list are: (1) Educational and Information Technology, (2) Psychology (Frontiers in Psychology), (3) Environment (International Journal of Environmental Research), and (4) Computers and Human Behavior.

The data show that the most cited work documents globally in the period 2014-2024 on TPACK tend to be interdisciplinary and integrated with technology, education, psychology, and the environment. The data indicate that most of the documents were published in 2020 and 2021, with only one document published in 2022. It can be said that the most citations tend to be for the latest works, published within the last 2-3 years.

Figure 9. The Most Global Cited Documents

ISSN: 2797-3174

Table 1. The Most Global Cited Documents

No	Document Name	Number of Global Citations
1.	Turnbull D, 2021, Education and Information Technologies	243
2.	Gao LX, 2020, Frontiers in Psychology	200
3.	Luan H, 2020, Frontiers in Psychology	169
4.	Panisoara IO, 2020, International Journal of Environmental Research	136
5.	Seufert S, 2020, Computers in Human Behavior	133
6.	Abilleira MP, 2021, Frontiers in Psychology	101
7.	Fernandez-batanero J, 2021, International Journal of Environmental Research	95
8.	Fawns T, 2022, Postdigital Science and Education	92
9.	Clark-wilson A, 2020, ZDM - Mathematics Education	92
10.	Shamir-inbal T, 2021, Journal of Educational Computing Research	89

3.1.9. Thematic Maps

Thematic maps are useful analyses to identify the main topics, themes, and issues that are researched and published. Figure 10 provides a comprehensive overview of the main topics that are the focus of TPACK's scientific research and inter-topic relationships.

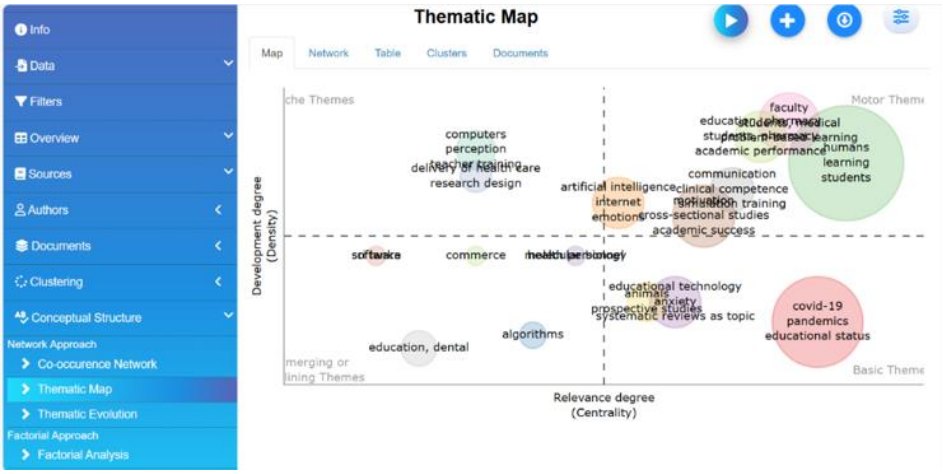

Figure 10: Thematic Map

Figure 10 provides information about the thematic map of TPACK. The information can be explained below.

a. Various main themes were identified, including: computers, perception, healthcare delivery, research design, artificial intelligence, clinical competence, and others.

b. These themes are positioned based on two main dimensions: degree of relevance/centrality and similarity of themes (development degree).

c. Themes that are close to each other show higher interconnectedness and similarity, while themes that are far apart show lower interconnectedness.

d. There are several clusters or groupings of themes, such as "emerging or joining Themes" and "Basic Themes".

e. In addition to the main theme, other topics have emerged such as COVID-19, pandemics, educational status, and others.

f. In the image, it appears to be divided into four quadrants, which provides information that the topics in the fourth quadrant are themes that have relevance to the main topic but the degree of interconnectedness or centrality is relatively smaller than the main themes in the centre of the map.

In other words, the themes in the fourth quadrant can be interpreted as topics that, although they appear in related research, are more peripheral or not the main focus.

ISSN: 2797-3174

3.2. Discussion

This bibliometric analysis provides a macro-level understanding of the intellectual, structural, and thematic evolution of TPACK research from 2014 to 2024. Rather than merely indicating growth, the findings reveal important shifts in knowledge production patterns, collaboration dynamics, and thematic transformations that shape the current trajectory of TPACK scholarship.

3.2.1. Intellectual Growth and Structural Expansion of TPACK Research

The identification of 500 documents across 153 journals, with an annual growth rate of 45.32%, indicates not only quantitative expansion but also structural diversification of the field. Such rapid growth reflects the increasing institutionalization of TPACK as a central framework in educational technology research. This expansion aligns with systematic reviews highlighting the continued relevance of TPACK in understanding teacher competence in digital contexts (Schmid et al., 2024; Tseng et al., 2022).

However, the dispersion of publications across 153 journals suggests both interdisciplinarity and fragmentation. On one hand, this diversity signals that TPACK has transcended its origins in teacher education and entered domains such as psychology, health sciences, and artificial intelligence. On the other hand, fragmentation may hinder theoretical consolidation, as research conversations become distributed across disciplinary silos. This condition echoes concerns raised by Schmid et al. (2024) regarding conceptual circularity and the need for stronger theoretical integration within TPACK scholarship.

The relatively moderate international collaboration rate (22.4%) further reinforces this interpretation. Although TPACK inherently integrates technology, pedagogy, and content, cross-national research networks remain limited. This suggests that while the framework is globally recognized, knowledge production may still be regionally concentrated and insufficiently interconnected.

3.2.2. Publication Peak and the Pandemic Effect

The peak in 2022 (190 publications) is unlikely to be coincidental. Instead, it reflects the global acceleration of digital transformation during and after the COVID-19 pandemic. The pandemic created an unprecedented shift toward emergency remote teaching, forcing educators worldwide to operationalize TPACK principles in practice (Su, 2023; Ozden et al., 2024).

This surge can be interpreted as a reactive wave of scholarship responding to urgent educational disruptions. The subsequent decline in 2023–2024 does not necessarily indicate reduced relevance; rather, it may signal a transition from emergency-driven research to more reflective and theoretically grounded investigations. In this sense, TPACK research appears to be moving from crisis response toward post-pandemic stabilization and integration.

Importantly, the temporal clustering of highly cited works around 2020–2021 suggests that impactful contributions were those that addressed immediate pedagogical and technological challenges. This pattern demonstrates how global crises can accelerate both research productivity and citation impact.

3.2.3. Geographical Concentration and Knowledge Imbalance

The dominance of countries such as China and Australia indicates strong national investment in educational technology research. These countries likely benefit from policy-level support, research funding, and institutional infrastructures that prioritize digital innovation in education. However, the underrepresentation of developing countries reveals a structural imbalance in global TPACK scholarship. Given that technological integration challenges are often more complex in resource-constrained environments, this imbalance limits the contextual diversity of theoretical development. As Huang and Musah (2024) note, expanding geographical representation is essential for ensuring that TPACK evolves as a globally relevant framework rather than one shaped primarily by technologically advanced systems.

The three-field analysis further suggests that certain countries specialize in specific thematic clusters. This thematic-national alignment may reflect contextual educational priorities but may also restrict cross-contextual theoretical enrichment. Strengthening international collaboration could therefore enhance comparative research and contextual adaptation of TPACK.

3.2.4. Thematic Evolution: From Professional Competence to Crisis Response and AI

ISSN: 2797-3174

The thematic analysis reveals three major developmental phases:

a. Professional and disciplinary focus (2016–2018) Early emphasis on teacher education, nursing education, and domain-specific applications indicates efforts to operationalize TPACK within particular professional contexts.

b. Technology integration and pandemic adaptation (2018–2022) The rise of keywords such as computer-assisted instruction, COVID-19, and pandemics reflects the urgent integration of digital tools into mainstream teaching.

c. Emerging digital intelligence themes (2022–2024) The appearance of themes such as artificial intelligence and algorithmic technologies suggests a conceptual shift toward what Celik (2023) terms "Intelligent TPACK," where ethical AI integration becomes central.

This progression demonstrates that TPACK is not a static framework but an adaptive one. Its thematic flexibility enables it to respond to technological advancements and global disruptions. However, the presence of emerging themes in peripheral quadrants of the thematic map suggests that areas such as AI ethics, algorithmic literacy, and advanced digital ecosystems are still developing and require further theoretical grounding.

3.2.5. Source and Citation Patterns: Interdisciplinary Legitimization

The dominance of journals such as Frontiers in Psychology and Education and Information Technologies indicates that TPACK research is strongly embedded in psychology and educational technology domains. This interdisciplinary anchoring enhances theoretical robustness by incorporating perspectives on cognition, motivation, digital literacy, and behavioral change (Schmid et al., 2021).

Highly cited documents tend to intersect education, psychology, and technology. This suggests that influential TPACK research is not purely descriptive but integrative, connecting teacher knowledge with learner psychology, digital tools, and systemic transformation. Citation impact thus appears linked to conceptual integration rather than narrow technical application. Moreover, the prominence of recent publications among the most cited works highlights the field's sensitivity to contemporary challenges. In fast-evolving technological landscapes, conceptual relevance and timeliness may drive citation performance more strongly than historical longevity.

3.2.6. Author and Institutional Stratification

The stratification pattern among authors indicates the emergence of core contributors who shape research directions. Such concentration of productivity may foster coherence and sustained theoretical development. However, it may also risk intellectual centralization if diverse perspectives are underrepresented. Institutional dominance particularly from ministries of education and research-intensive universities illustrates the role of policy and institutional ecosystems in driving TPACK scholarship. Government-linked institutions, such as the Ministry of Education Malaysia, reflect alignment between national education reforms and research agendas. This suggests that TPACK research is not merely academic but policy-relevant and reform-oriented.

Interestingly, the presence of medical faculties and hospitals among top affiliations underscores TPACK's expansion beyond traditional school settings. The integration of TPACK in health and clinical education reflects broader digital transformation across professional education sectors.

3.2.7. Theoretical and Practical Implications

From a theoretical perspective, this bibliometric mapping indicates that TPACK is transitioning from a teacher-competency framework toward a broader digital knowledge paradigm encompassing AI, digital ethics, and cross-disciplinary integration. Future theoretical development should therefore focus on:

a. Integrating AI literacy and data ethics into TPACK models.

b. Strengthening cross-cultural validation of TPACK constructs.

c. Addressing conceptual fragmentation through integrative meta-theoretical synthesis.

From a practical standpoint, the findings suggest that sustainable TPACK implementation requires:

ISSN: 2797-3174

a. Institutional policy support.

b. Structured professional development programs.

c. International collaboration networks to share contextual practices.

Without these systemic supports, TPACK risks remaining a conceptual ideal rather than an operationalized framework in diverse educational systems.

3.2.8. Synthesis

Overall, this study demonstrates that TPACK research has evolved from conceptual adaptation of PCK into a globally recognized interdisciplinary field responding dynamically to technological and societal changes. While growth is substantial, challenges remain in terms of geographical balance, theoretical consolidation, and deep integration of emerging technologies such as artificial intelligence. By moving beyond descriptive publication counts and examining structural, thematic, and collaborative patterns, this discussion highlights not only where TPACK research stands today but also where it must advance to remain theoretically relevant and practically transformative in the digital era.

3.3. Practical Implications for TPACK Scholarship

This study also provides important practical implications for educators, teacher educators, and policymakers:

a. For Teacher Education Programs: Institutions should design structured, practice-based TPACK training that integrates technology planning cycles, reflective practice, and collaborative lesson design rather than focusing solely on technical skill development.

b. For Educational Leaders: Policymakers and administrators should ensure institutional support systems such as infrastructure, mentoring, and continuous professional development to facilitate meaningful technology integration.

c. For Researchers: The identification of dominant themes and underexplored topics offers a strategic roadmap for advancing theory-building efforts and fostering stronger research networks.

d. For Curriculum Developers: The thematic evolution identified in this study suggests the importance of aligning curriculum innovation with emerging digital competencies and global educational challenges.

This bibliometric analysis not only maps the intellectual landscape of TPACK research but also highlights strategic directions for strengthening its theoretical depth, methodological rigor, and global relevance. By encouraging interdisciplinary collaboration, methodological diversification, and inclusive knowledge production, future TPACK scholarship can play a pivotal role in shaping sustainable and context-responsive technology integration in education.

3.4. Recommendations for Future Research

Based on the findings of this bibliometric mapping, several directions for future research are proposed:

a. Strengthening Cross-National and Interdisciplinary Collaboration: Future studies should prioritize collaborative projects that involve researchers from underrepresented regions, particularly developing countries. Comparative cross-country studies can provide deeper insights into contextual differences in TPACK implementation and policy development.

b. Expanding Research into Emerging Technologies: As artificial intelligence, generative AI, augmented reality, and learning analytics continue to reshape education, future TPACK research should examine how these technologies transform teachers' knowledge structures and instructional decision-making processes.

c. Moving Beyond Self-Reported Measures: Much of the existing TPACK research relies on self-reported instruments. Future research should incorporate classroom observations, performance-based assessments, experimental designs, and longitudinal studies to better understand the actual impact of TPACK on teaching effectiveness and student outcomes.

d. Exploring Institutional and Policy-Level Factors: Further investigation is needed into how institutional leadership, curriculum design, teacher professional development models, and national education policies influence sustainable TPACK integration.

ISSN: 2797-3174

e. Developing Context-Sensitive TPACK Models: Researchers are encouraged to develop adaptive or localized TPACK frameworks that consider cultural, infrastructural, and socio-economic factors, particularly in low-resource educational settings.

4. Conclusion

This bibliometric analysis demonstrates that TPACK research has experienced substantial growth over the past decade, with a significant publication peak in 2022. The increasing number of publications, the diversity of contributing journals, and the emergence of leading authors and institutions indicate that TPACK has become a well-established and dynamic research domain. The strong involvement of institutions such as the Ministry of Education Malaysia and several international universities reflects the importance of institutional support and cross-sector collaboration in advancing TPACK scholarship. Furthermore, the thematic evolution from early emphases on nursing education and computer-assisted instruction to more recent concerns such as COVID-19, digital transformation, and human-centered learning illustrates the field's responsiveness to global educational challenges. However, the findings also reveal structural imbalances in the development of TPACK research. Contributions remain concentrated in specific countries, while developing regions are underrepresented. International collaboration, although present, has not yet reached its full potential considering the interdisciplinary nature of TPACK. These patterns suggest the need for a more inclusive and globally integrated research agenda.

Author Contributions

Author 1: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft. Author 2: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing – original draft. Author 3: Data curation, Resources, Visualization, Writing – review & editing. Author 4: Supervision, Project administration, Funding acquisition, Validation, Writing – review & editing. All authors have contributed equally to this manuscript. All authors have read and approved the final version of the manuscript.

Funding

No funding support was received.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to data management and repository limitations but are available from the corresponding author upon reasonable request. The shared data include bibliometric metadata extracted from the Dimensions database and processed using R Studio with the Bibliometrix package. All data have been handled in accordance with ethical research standards.

Declaration on AI Use

The authors declare that artificial intelligence (AI) or AI-assisted technologies were used solely to improve language clarity and readability under full human supervision. AI tools did not generate scientific content, data analyses, interpretations, conclusions, or recommendations, and AI was not listed as an author.

Acknowledgement

The authors would like to thank all institutions and database providers whose open-access resources supported this bibliometric study. Appreciation is also extended to colleagues and reviewers who provided constructive feedback that helped improve the quality of this manuscript.

References

Absari, N., Priyanto, P., & Muslikhin, M. (2020). The effectiveness of technology, pedagogy and content knowledge (TPACK) in learning. *Jurnal Pendidikan Teknologi Dan Kejuruan, 26*(1), 43–51. doi:10.21831/jptk.v26i1.24012

Albloushi, M., Aldawsari, A. N., Alghamdi, R., Alenazy, B., Alanazi, H., Almutairi, H. (2024). Nurse educator's experiences and challenges with online teaching: A qualitative descriptive study. *Heliyon, 10*(8), e29533. doi:10.1016/j.heliyon.2024.e29533

Ammade, S., Mahmud, M., Jabu, B., & Tahmir, S. (2020). TPACK model based instruction in teaching writing: An analysis on TPACK literacy. *International Journal of Language Education, 4*(1), 129–140. doi:10.26858/ijole.v4i2.12441

Backfisch, I., Sibley, L., Lachner, A., Kirchner, K. T., Hische, C., & Scheiter, K. (2024). Enhancing pre-service teachers' technological pedagogical content knowledge (TPACK): Utility-value interventions support knowledge integration. *Teaching and Teacher Education, 142*, 104532. doi:10.1016/j.tate.2024.104532

ISSN: 2797-3174

Balalle, H. (2024). Exploring student engagement in technology-based education in relation to gamification, online/distance learning, and other factors: A systematic literature review. *Social Sciences & Humanities Open, 9*, 100870. doi:10.1016/j.ssaho.2024.100870

Baran, E., Canbazoglu Bilici, S., Albayrak Sari, A., & Tondeur, J. (2019). Investigating the impact of teacher education strategies on preservice teachers' TPACK. *British Journal of Educational Technology, 50*(1), 357–370. doi:10.1111/bjet.12565

Bhat, W. A. (2023). How to conduct bibliometric analysis using R-studio: A practical guide. *European Economic Letters, 13*(3). doi:10.52783/eel.v13i3.350

Browning, M., Banik, B., Bourke, S., Abdelkader, A., Anish, L., & Muduwa, M. (2023). The impact of COVID-19 restrictions on Australian nurse academics' attitudes to technology: A survey of technology readiness index 2.0. *Nurse Education in Practice, 71*, 103719. doi:10.1016/j.nepr.2023.103719

Celik, I. (2023). Towards intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior, 138*, 107468. doi:10.1016/j.chb.2022.107468

Dogan, S., Dogan, N. A., & Celik, I. (2021). Teachers' skills to integrate technology in education: Two path models explaining instructional and application software use. *Education and Information Technologies, 26*(1), 1311–1332. doi:10.1007/s10639-020-10310-4

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133*, 285–296. doi:10.1016/j.jbusres.2021.04.070

Foulger, T. S., Jin, Y., Mourlam, D. J., & Ebersole, L. (2022). Equitable access to TPACK research: Tensions about using social media to disseminate scholarship. *Computers and Education Open, 3*, 100067. doi:10.1016/j.caeo.2021.100067

Hakkarainen, T., Salminen, L., Alastalo, M., & Virtanen, H. (2024). Online degree programmes in nurse education—Students' perceptions and academic performance: An integrative review. *Nurse Education Today, 136*, 106148. doi:10.1016/j.nedt.2024.106148

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action. *Journal of Research on Technology in Education, 43*(3), 211–229. doi:10.1080/15391523.2011.10782570

Hieu, H. L., Thanh, H. P. T., & Luong, D. H. (2024). A dataset of Vietnamese university lecturers' teaching skills: A TPACK model. *Data in Brief, 55*, 110551. doi:10.1016/j.dib.2024.110551

Huang, L., & Musah, A. A. (2024). The influence of augmented reality on creativity, student behavior, and pedagogical strategies in technology-infused education management. *Journal of Pedagogical Research, 8*(2), 260–275. doi:10.33902/JPR.202425376

Huq Shamim, M. R., Jeng, A. M., & Raihan, M. A. (2024). University teachers' perceptions of ICT-based teaching to construct knowledge for effective classroom interaction in the context of TPACK model. *Heliyon, 10*(8), e28577. doi:10.1016/j.heliyon.2024.e28577

Lee, D., Arnold, M., Srivastava, A., Plastow, K., Strelan, P., Ploeckl, F., ... Palmer, E. (2024). The impact of generative AI on higher education learning and teaching: A study of educators' perspectives. *Computers and Education: Artificial Intelligence, 6*, 100221. doi:10.1016/j.caeai.2024.100221

Lyublinskaya, I., & Kaplon-Schilis, A. (2022). Analysis of differences in the levels of TPACK: Unpacking performance indicators in the TPACK levels rubric. *Education Sciences, 12*, 79.

Mukherjee, D., Lim, W. M., Kumar, S., & Donthu, N. (2022). Guidelines for advancing theory and practice through bibliometric research. *Journal of Business Research, 148*, 101–115. doi:10.1016/j.jbusres.2022.04.042

Ninkov, A., Frank, J. R., & Maggio, L. A. (2022). Bibliometrics: Methods for studying academic publishing. *Perspectives on Medical Education, 11*(3), 173–176. doi:10.1007/s40037-021-00695-4

Ntshingila, N., Downing, C., Rathaba, D. D., & Hastings-Tolsma, M. (2024). COVID-19 and nurse faculty caring: A meta-synthesis. *Heliyon, 10*(7), e28472. doi:10.1016/j.heliyon.2024.e28472

Ozden, S. 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. doi:10.1016/j.ssaho.2024.100869

Pessin, V. Z., Yamane, L. H., & Siman, R. R. (2022). Smart bibliometrics: An integrated method of science mapping and bibliometric analysis. *Scientometrics, 127*(6), 3695–3718. doi:10.1007/s11192-022-04406-6

Prasetiyo, W. H., Sari, B. I., Naidu, N. B. M., Sa'diyah, H., Saputri, R. N., Dewantara, J. A., ... Patmisari. (2022). Dataset of TPACK in teaching practice: Adversity quotient, attitude computer technology and self-efficacy among Indonesian teachers. *Data in Brief, 45*, 108749. doi:10.1016/j.dib.2022.108749

Santos, J. M., & Castro, R. D. R. (2021). Technological pedagogical content knowledge (TPACK) in action: Application of learning in the classroom by pre-service teachers (PST). *Social Sciences & Humanities Open, 3*(1), 100110. doi:10.1016/j.ssaho.2021.100110

Schmid, M., Brianza, E., Mok, S. Y., & Petko, D. (2024). Running in circles: A systematic review of reviews on technological pedagogical content knowledge (TPACK). *Computers & Education, 214*, 105024. doi:10.1016/j.compedu.2024.105024

ISSN: 2797-3174

Schmid, M., Brianza, E., & Petko, D. (2021). Self-reported technological pedagogical content knowledge (TPACK) of pre-service teachers in relation to digital technology use in lesson plans. *Computers in Human Behavior, 115*, 106586. doi:10.1016/j.chb.2020.106586

Schubatzky, T., Burde, J. P., Große-Heilmann, R., Haagen-Schützenhöfer, C., Riese, J., & Weiler, D. (2023). Predicting the development of digital media PCK/TPACK: The role of PCK, motivation to use digital media, interest in and previous experience with digital media. *Computers & Education, 206*, 104900. doi:10.1016/j.compedu.2023.104900

Shabur, M. A., & Siddiki, M. R. (2024). Investigating social media's impact on the new era of interactive learning: A case study of Bangladesh. *Heliyon, 10*(4), e26234. doi:10.1016/j.heliyon.2024.e26234

Su, Y. (2023). Delving into EFL teachers' digital literacy and professional identity in the pandemic era: Technological pedagogical content knowledge (TPACK) framework. *Heliyon, 9*(6), e16361. doi:10.1016/j.heliyon.2023.e16361

Thomas, A. A., Montgomery, E. E., Abulebda, K., Whitfill, T., Chapman, J., Leung, J., ... Auerbach, M. (2023). The feasibility of a pediatric distance learning curriculum for emergency nurses during the COVID-19 pandemic: An improving pediatric acute care through simulation collaboration. *Journal of Emergency Nursing, 49*(1), 27–39. doi:10.1016/j.jen.2022.09.001

Tseng, J. J., Chai, C. S., Tan, L., & Park, M. (2022). A critical review of research on technological pedagogical and content knowledge (TPACK) in language teaching. *Computer Assisted Language Learning, 35*(4), 948–971. doi:10.1080/09588221.2020.1868531

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

ISSN: 2797-3174