Vol. 14, No. 01, pp. 352-369, 2024 DOI: 10.23960/jpp.v14.i1.202426

Jurnal Pendidikan Progresif

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jurnal.fkip.unila.ac.id/index.php/jpp/

Research Trends in Technological Pedagogical Content Knowledge (TPACK) Research (2014-2024): A Scientometric Analysis

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Received: 11 April 2024 *Accepted: 05 May 2024* *Published: 09 May 2024*

Abstract: Research Trends in Technological Pedagogical Content Knowledge (TPACK) Research (2014-2024): A Scientometric Analysis. Objectives: Over the past 20 years, there has been significant progress in TPACK research. Rapid technological advances make research on TPACK very important. However, very few studies have examined references through the application of scientometric analysis. This study aims to identify current and future TPACK trends, subjects, publications, authors, keywords, and author collaboration networks in TPACK research. **Methods:** Scientometric analysis was carried out on data from the Scopus database, a total of 582 TPACK research publications published from 2014 to March 2024 with keyword Technological Pedagogical Content Knowledge. We also restrict content written in English and limit to final publication stage. This study analysis does not include books, newspaper articles, and book reviews. Data analysis used the R bibliometric packages biblioshiny and VOSviewer. **Findings:** Based on the analysis results, the keywords that appeared most frequently in publications were TPACK (194 articles). The Australian Journal of Educational Technology is the journal that publishes the most articles on the TPACK theme (24 articles) and also has the highest number of local citations. Chai is number one on the list of authors with the highest impact. Based on the co-occurrence network visualization and word cloud, the organizational support, especially school support, is not yet visible. China, Indonesia, Australia, and the USA are leaders in collaboratives about TPACK topic. **Conclusion:** This study provides in-depth information about keywords are most pertinent to research on TPACK; journals that hold significant influence, and authors demonstrate prolificacy in studies concerning TPACK; the current trends in TPACK research, and what priority areas warrant further investigation; and the collaborative networks among countries in TPACK research.

Keywords: TPACK, scientometric, biblioshiny, research trends.

To cite this article:

Krisnaresanti, A., Ahman, E., Istikomah, N., Suwatno, & Budiman, A. (2024). Research Trends in Technological Pedagogical Content Knowledge (TPACK) Research (2014-2024): A Scientometric Analysis. *Jurnal Pendidikan Progresif*, *14*(1), 352-369. doi: 10.23960/jpp.v14.i1.202426.

INTRODUCTION

Technological Pedagogical and Content Knowledge (TPACK) is a framework developed by Matthew J. Koehler and Punya Mishra in the early 21st century. TPACK was first introduced in their article "What Happens When Teachers Design Educational Technology? The Development of Technological Pedagogical Content Knowledge" published in 2006. Koehler and Mishra responded to the need to understand the complexity of interactions between technology, pedagogy, and content in the context of teaching and learning. They recognize that effective teachers integrating technology into their

teaching practices require strong technological knowledge, a deep understanding of subject content, and effective teaching strategies (Mishra, P., & Koehler, 2006).

TPACK is a framework that combines three main types of knowledge teachers possess, including Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). TK is an understanding of various tools and technologies that can support learning. TK includes knowledge of how to use hardware, software, and online and multimedia resources. PK is knowledge of effective teaching strategies and learning practices, including understanding how students learn and interact with lesson material. PK includes knowledge of conveying information, managing a classroom, and facilitating student learning. CK refers to teachers' understanding of the material or content of their lessons. CK includes a deep understanding of the concepts, principles, and theories in the subjects taught. TPACK combines these three types of knowledge in a holistic framework and emphasizes the importance of interaction and integration between them. This framework guides teachers in designing, developing, and implementing effective teaching using technology in learning contexts appropriate to the subject content. Every learning with technology aims to provide quality learning, leading to learning engagement, positive learning outcomes, and satisfaction (Sahni, 2019).

Reviewing academic publications can help one understand trends in a research topic (Tseng et al., 2020). Articles can provide a comprehensive understanding of existing studies and address implications drawn from review results (Al-Emran et al., 2018). Previous literature studies have discussed TPACK research trends (Dewi et al., 2021; H. Y. Lee et al., 2022; Marlina et al., 2023; Sofwan et al., 2024; Su, 2023). This literature study discusses several things, such as the development of TPACK, instruments to assess TPACK and TPACK relationships with technology integration. The Systematic Literature Review produced by Dewi et al. (2021) from 2010 to 2020 analyzing topics related to Technological Pedagogical Content Knowledge (TPACK) revealed that the knowledge components most researched in TPACK are Knowledge, Technology, Content, and Pedagogy. Additionally, there are topics related to learning, teaching, and education. There are teachers and pre-service teachers who teach mathematics and science subjects. However, the least researched topic is development and integration. This shows that researchers have not shown much interest in these two topics over the past decade.

Another literature review was conducted by Tseng (2020) based on the need for literature reviews regarding language teachers' knowledge of language teaching with technology. A review study was conducted to increase understanding of the landscape of TPACK research on language teachers published from 2011 to 2019. The results of the analysis revealed that 51 studies were identified and most of them were conducted in Central Asia and East Asia. Articles were categorized into four areas: (a) TPACK exploration, (b) TPACK assessment, (c) TPACK development, and (d) TPACK implementation. The results show that although teachers have varying levels of confidence in their TPACK competencies, in traditional teacher-centered learning, teachers predominantly use technology in teaching.

In several literature studies, limitations were still found. First, still mainly focuses on examining teacher TPACK from the perspective of knowledge rather than competence (Lee et al., 2021). Second, the sample and the method (Sofwan et al., 2024). Third, the review studies that have already been done have had narrow perspectives. For example, focused on instruments to assess TPACK, TPACK domains'

inter-correlation, and TPACK relationships with technology integration (Sofwan et al., 2024), whereas Marlina (2023) only analyzed the TPACK in a single subject, namely TPACK in chemistry education. Fourth, providing only a retrospective account of previous efforts rather than recommendations for future courses of action. These characteristics mean that the review studies from the past need to capture the state-of-the-art developments in research on TPACK fully. It still needs to be possible to conduct a thorough analysis that can offer a comprehensive perspective and insight into the development of TPACK theory.

This study is the first to use quantitative tools to comprehensively analyze the fundamental ideas and the overall state of collective knowledge regarding innovation inside the TPACK to close this gap. By defining the breadth, evaluating the caliber of the body of knowledge, and selecting the most pertinent areas for future research, this study advances TPACK development. The following research topics are intended to be addressed by this study using scientometric analysis: 1) Which keywords are most pertinent to research on TPACK?; 2) Which journals hold significant influence, and which authors demonstrate prolificacy in studies concerning TPACK?; 3) What are the current trends in TPACK research, and what priority areas warrant further investigation?; and 4) How might we chart and analyze the collaborative networks among countries in TPACK research?

METHOD

Research design

Scientific research undergoes a quantitative examination in the form of scientometric analysis (Yalcinkaya & Singh, 2015). This method uses trends from academic databases to map a particular knowledge area, assess the impact of research, and look into citation links. A manual literature review can provide a thorough overview of a particular field of study, but it is still biased and open to personal interpretation (Pollack & Adler, 2015). It involves using various tools and software to analyze and visualize scientific research data, such as the Web of Science, CiteSpace, VOSviewer, Biblioshiny, and Bibliometrics. These tools help identify research hotspots and collaborations between authors, organizations, and countries and map the structure of scientific knowledge.

In scientometric analysis, we examine and assess the attributes of keywords, journals, and clusters based on a specific collection of journal articles. This method allows researchers to gain insights into the trends and patterns of research activity, identify critical contributors and publications, and assess the impact and influence of different research areas or disciplines. By applying statistical and mathematical techniques, scientometric analysis quantitatively evaluates publications, patents, citations, and other elements to develop indicators for evaluating scientific performance and technological advancements. This method facilitates understanding the evolution of specific research fields, identifying emerging trends and hot topics, and predicting future directions of scientific developments. It aids researchers and policymakers in making informed decisions, identifying research gaps, and allocating resources effectively. Additionally, scientometric analysis identifies collaborations and networks within the research community, highlighting meaningful collaborations and influential researchers.

Search Strategy

The scientometric analysis is the most appropriate method for the current study because it focuses on quantitative measurements, trends, and data-driven insights into TPACK. We conducted this scientometric analysis to guarantee objectivity and openness using the Preferred Reporting Items for Systematic Reviews and

Meta-Analysis (PRISMA) criteria (Figure 1). From Stage One to Stage Three, we employ this strategy. The fourth step of data processing involves scientometric analysis and visual mapping. The methodology employed was derived from the works of Hakam (2023) and Leitão et al (2023).

In the initial stage, we specified the strings in the Scopus database, executing structured searches using the authors' chosen keywords. Since Scopus is a multidisciplinary database that covers the most cited and indexed journals in several scientific subspecialties, Scientometric used it for this analysis. A more extensive collection of peer-reviewed scientific articles is among the many publications available in the Scopus database. In March 2024, we searched data using "technological pedagogical and content knowledge" on every topic. We gathered 2.236 papers from the study we conducted in this initial phase. In the second phase, we read and eliminated duplicates of the article title, abstract, and keywords. When required, we comprehensively examined the article's content to ensure consistency in interpretation and importance.

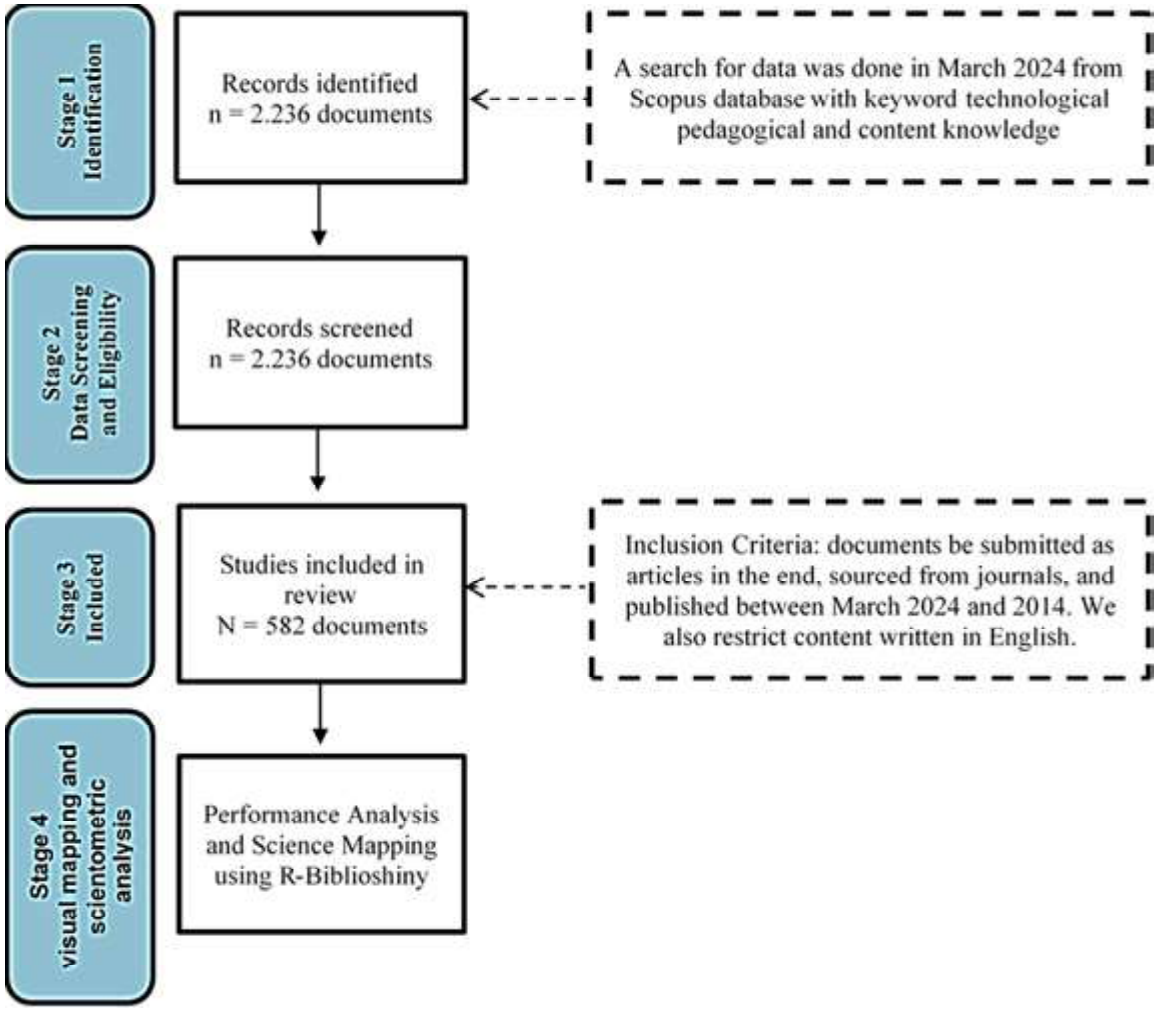

Figure 1. Methodology for article selection and analysis

Inclusion and Exclusion Criteria

In the third step, we established the inclusion criteria, requiring materials to be submitted as journal articles and published between March 2024 and 2014. We also restrict content written in English. This study analysis does not include books, newspaper articles, and book reviews. Thus, the last string entered into the Scopus database looked like this: TITLE-ABS-KEY (technological AND pedagogical AND content AND knowledge) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (OA, "all")). There ultimately 582 papers left.

Data Analysis

Next, to create and visualize the bibliometric network and show the citation matrix, the bibliometric data for the 582 texts were analyzed using R-biblioshiny. We performed visual mapping and scientometric analysis in the fourth step. According to Patra and Muchie (2021), "scientometric analysis" is broad and includes quantitative approaches for researching science and technology in addition to bibliometric analysis. This approach seeks to assess the impact and influence of scientific research, map the scientific landscape, and detect research trends. In order to shed light on this fascinating area of research, it offers academics some views based on the primary findings that scientometric methodologies provide via direct citation, i.e., Global and Local Citation (Batista-Canino et al., 2023).

■ RESULT AND DISCUSSION

Descriptive Analysis and Keywords are most pertinent to research on TPACK

The publication used in this research is from 2014 to 2024, approximately a decade, from 230 journal sources with 582 articles. From the Biblioshiny report (Table 1), based on the Scopus dataset, there are 1.577 authors, with 101 non-collaborating authors in 103 articles. The annual growth rate of this publication trend is 2.92%. Table 2 presents the keywords used in the search. In Scopus filters, select 'keyword' from the left-hand column to see all of the keywords related to all of the results for your search. Subject areas

Table 1. Main data information

Description	Results	Description	Results
Main Information About Data		**Authors**	
Timespan	2014:2024	Authors	1577
Sources (Journals, Books, etc.)	230	Authors of single-authored docs	101
Documents	582	**Authors Collaboration**	
Annual Growth Rate %	2.92	Single-authored docs	103
Document Average Age	3.5	Co-Authors per Doc	3.04
Average citations per doc	11.78	International co-authorships %	19.07
References	26154	DOCUMENT TYPES	
DOCUMENT CONTENTS		article	582
Keywords Plus (ID)	573		
Author's Keywords (DE)	1541		

don't accurately describe material as much as keywords do. The most frequently occurring keywords in publications are TPACK (194 articles), followed by technological pedagogical content knowledge (91 articles) and technology integration (48 articles). Overall, publications with the Technological Pedagogical Content Knowledge theme have continued to increase. Publications increased from 2019 until 2023, despite some oscillations between 2014 and 2018. The most publications with the theme of TPACK were found in 2023, with a total of 140 articles. Overall, publications with the theme of TPACK are trending upward. Meanwhile, citation trends peaked in 2020.

Table 2. Top 20 keywords used in the iterative process

Keyword	Articles	Keyword	Articles
TPACK	194	Education	25
Technological Pedagogical Content Knowledge	91	Educational Technology	25
Technology Integration	48	Higher Education	24
Teaching	46	Learning	23
Technology	39	COVID-19	22
Teacher Education	38	Content Knowledge	22
Pre-service Teachers	31	Technological Knowledge	22
Technological Pedagogical Content Knowledge (TPACK)	31	Pedagogy	20
Professional Development	28	E-learning	17
Engineering Education	27	Online Learning	17

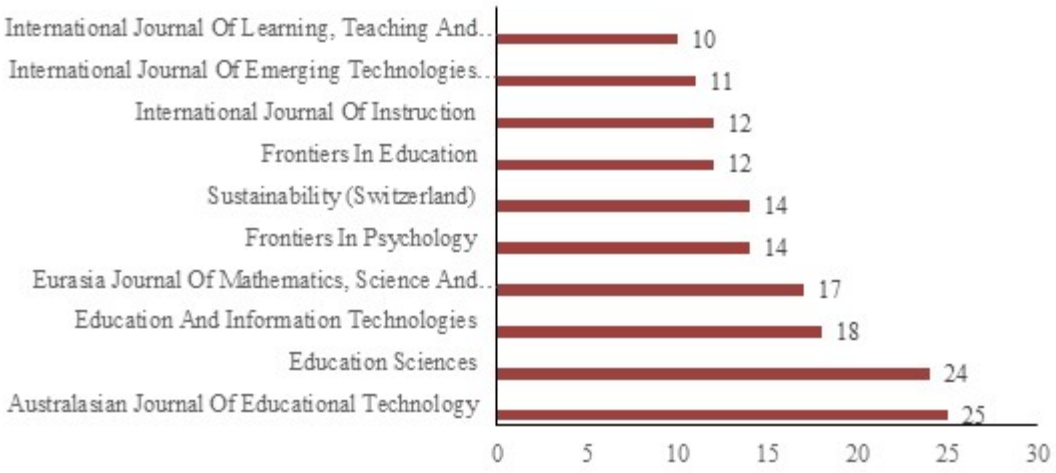

Figure 2. Most relevant sources

Journals Hold Significant Influence, and Authors Demonstrate Prolificacy of Studies Concerning TPACK

Figure 2 shows the distribution of the top ten most relevant sources. With 25 papers published, the Australian Journal of Educational Technology comes in first, followed by "Education Sciences" (24 papers) and "Education and Information Technologies" (18 papers). Meanwhile, Figure 3 shows the most influential journal based on the total number of local citations. Locally, based on the data used (582 articles), the most cited journal locally is the Australian Journal of Educational Technology, with an h-index of 16. The h-index assesses an author's overall intellectual effect over time. A high h-index will not be produced by too many articles with few citations or by too few highly cited papers. Instead, it assesses a researcher's quantitative (productivity) and qualitative (citations) research effort as a single number (Atwan et al., 2020).

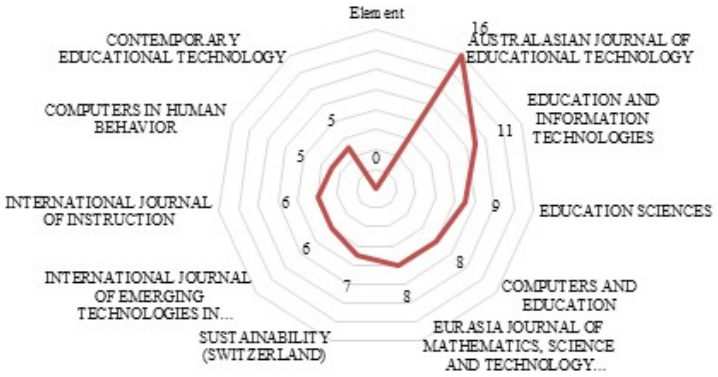

Figure 3. Sources' local impact by h index

An effective method for examining an author's output and influence on scholarly publications is citation analysis (Nightingale & Marshall, 2012). Author impact metrics are measures used to assess the influence of an author's, a lab's, or an organization's academic publications. The quantity of articles and citations determines them. The h-Index is one of the most well-known author metrics. H-index (or Hirsch index) is the most used author metric. It was created by the physicist Jorge E. Hirsch in 2005 (Hirsch, 2005). It is based on the number of publications and the number of citations. Due to differences in each database's coverage (years and types of sources), different databases will different h-indices (Harzing & Alakangas, 2016).

Table 3 Author local impact by h-index

Element	h_index	g_index	m_index	TC	NP	PY_start
Chai CS	8	9	0.8	258	9	2015
Tondeur J	7	8	0.875	562	8	2017
Habibi A	5	7	0.83333333	54	8	2019
Mukminin A	5	6	0.83333333	53	6	2019
Voogt J	5	5	0.5	257	5	2015
Baran E	4	4	0.5	380	4	2017
Mckenney S	4	4	0.4	209	4	2015

Scherer R	4	4	0.5	380	4	2017
Siddiq F	4	4	0.5	380	4	2017
Drajati Na	3	4	0.42857143	46	4	2018

Chai is number one on the list of authors with the highest impact (Table 3). Chai CS has an h-index score of 8 meaning 8 articles are cited by at least 8 other articles. One of the articles Chai collaborated with Wong published profoundly impacted the journal entitled Employing the TPACK framework for researcher-teacher co-design of a mobile-assisted seamless language learning environment (Wong et al., 2015). This study used the TPACK framework to create the "MyCLOUD" learning environment. MyCLOUD promotes seamless, self-directed, and collaborative Chinese language study among primary students by integrating mobile and cloud technology. A different article looked at the relationship between the TPACK survey and lesson plan measures and their alignment with the measure of chemical epistemological views (Deng et al., 2017).

Tondeur (Second rank) collaborated with Scherer (Seventh rank) in an article entitled The Importance of Attitudes Toward Technology for Pre-Service Teachers' Technological, Pedagogical, and Content Knowledge: Comparing Structural Equation Modelling Approaches Show a meaningful methodological synergism and describe the TPACK-attitudes interactions from numerous viewpoints using a range of structural equation modelling methodologies. The studies showed a positive relationship between TPACK self-beliefs and attitudes toward technology. However, there were variations between the TPACK and attitude dimensions, indicating the separation of general and instructional viewpoints on ICT use (Scherer et al., 2018).

The latest article (Brianza et al., 2024) entitled The digital silver lining of the pandemic: The impact on preservice teachers' technological knowledge and beliefs collaborating with Brianza E., Schmid M., and Petko D. The study aims to shed light on how the pandemic affects prospective teachers' evaluations of their professional knowledge for teaching in the digital era as well as their beliefs regarding the usefulness of technology for education and the responsibility of the education system to develop students' technological competence. Initially, it was observed that following the lockdown, both inexperienced and seasoned pre-service teachers showed greater confidence in their subject-specific and broad technological expertise (e.g., kindergarten) when compared to pre-pandemic teachers. They are using technology to teach (TPCK, for example). Second, research on the beneficial effects of experience on the TPACK of aspiring teachers revealed that, except for the PCK and TCK categories, experienced educators scored substantially higher on TPACK than novices with no prior teaching experience. Third, there is preliminary evidence that CK and PCK have an experience-related advantage because the ratings for these domains given by experienced pre-service teachers were considerably higher after the lockdown than those given by rookie instructors before and after the lockdown. Lastly, the pandemic has not changed prospective teachers' perspectives on the use of technology in the classroom. In the Third rank, Habibi, in collaboration with Mukminin (Fourth rank), discussed Technology in the classroom for EFL teachers' technological pedagogical and content knowledge (Mukminin et al., 2020). The research findings indicated that teachers possessed a greater understanding of traditional, non-technology conceptions of pedagogy and content than they did of technological conceptions of pedagogy and content.

The most influential publication in terms of global citations (Table 4) is an article by Falloon (2020) published in 2020 in Educational Technology Research and Development. The article "From Digital Literacy to Digital Competence: The Teacher Digital Competency (TDC) Framework" has been cited 277 times. An enhanced definition of teacher digital competence (TDC), along with a conceptual framework, is presented in this article. It goes beyond the current conceptualizations of technology and literacy, advocating instead for more comprehensive and broad-based understandings that acknowledge the increasingly complex knowledge and abilities that young people require to operate morally, securely, and productively in various digitally mediated environments.

The second most globally cited article was obtained by Webb, et.al (2017) with the title "Computer Science in K-12 school curricula of the 2nd Century: Why, what and When?" The article was published in 2017 in the Education and Information Technologies with 144 citations. In this paper, in light of recent calls for curriculum reform, researchers have reviewed the place and functions of computer science in curricula. They also identified critical areas for future research and suggested guidelines and concerns for curriculum designers to consider. Critical viewpoints from curriculum theory, such as "powerful knowledge" as a crucial component of entitlement and management of the development of expertise, have been examined about emerging issues. Based on our investigation, they have determined areas of agreement as well as dangers, and topics that are still up for debate.

Scherer R., Tondeur J., Siddiq F., and Baran E. (2018) obtained the third most referenced article worldwide entitled "The Importance of Attitudes toward Technology for Pre-service Teachers' Technological, pedagogical, and Content Knowledge: Comparing Structural Equation modelling approaches" with 139 citations. This research expands our understanding of this relationship between three basic technology attitudes—general attitudes toward ICT, attitudes toward ICT in education, and ease of use—and TPACK self-efficacy beliefs. It is based on a sample of N = 688 prospective Flemish teachers in 18 teacher training institutions. Researchers propose substantive-methodological synergy and describe the interaction of TPACK attitudes from multiple viewpoints using various structural equation modelling methodologies. The research results show a positive relationship between TPACK self-confidence and attitudes towards technology. However, there are variations between the TPACK and attitude dimensions, indicating a separation of general and instructional viewpoints regarding ICT use.

Table 4. Top 10 cited documents of TPACK

Reference, Location	Title	Year	Source	Total Citation	Author Keywords
Falloon (2020), Australia	From digital literacy to digital competence: the teacher digital competency (TDC) framework	2020	Educational Technology Research and Development	277	Digital competence; Digital literacy; Integration; SAMR; Teacher education; Technology; TPACK

Webb et al. (2017), UK	Computer science in K-12 school curricula of the 2lst century: Why, what and when?	2017	Education and Information Technologies	144	Computer science; Curriculum design; Entitlement; Informatics; Powerful knowledge; Primary education; Secondary education
Scherer et al. (2018), Norway	The importance of attitudes toward technology for pre-service teachers' technological, pedagogical, and content knowledge: Comparing structural equation modeling approaches	2018	Computers in Human Behavior	139	Attitudes toward technology; Content knowledge (TPACK); Latent variable models; Pedagogical; Substantive-methodological synergism; Teacher education; Technological
Valtonen et al. (2017), Finland	TPACK updated to measure pre-service teachers' twenty-first century skills	2017	Australasian Journal of Educational Technology	120	-
Voogt & McKenney (2017), Netherland	TPACK in teacher education: are we preparing teachers to use technology for early literacy?	2017	Technology, Pedagogy and Education	116	early literacy; pre-service education; TPACK
Ke & Hsu (2015), USA	Mobile augmented-reality artifact creation as a component of mobile computer-supported collaborative learning	2015	Internet and Higher Education	114	Augmented reality; learning; Learning by making; Mobile computer-assisted collaborative; Technological pedagogical content knowledge
Schmid et al. (2020), Switzerland	Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model	2020	Computers and Education	104	Educational technology; Pre-service teachers; Self-report questionnaire; Technological pedagogical content knowledge; Transformative model

Jang et al. (2021), South Korea	Augmented Reality and Virtual Reality for Learning: An Examination Using an Extended Technology Acceptance Model	2021	IEEE Access	98	augmented reality; emerging technology; motivational support; social norm; technology acceptance model (TAM); Technology integration; TPACK; virtual reality
Nousiainen et al. (2018), Finland	Teacher competencies in game-based pedagogy	2018	Teaching and Teacher Education	96	Basic education; Case study; Educational technology; Game-based pedagogy; Primary school; Teacher competence
Baran et al. (2019), Turkey	Investigating the impact of teacher education strategies on preservice teachers' TPACK	2019	British Journal of Educational Technology	92	Digital competence; Digital literacy; Integration; SAMR; Teacher education; Technology; TPACK

The current trends in TPACK research and priority areas warrant further investigation.

This section uses the relationship between words (keyword plus) to help us understand diverse themes in TPACK. The study first suggests a co-occurrence network to assess various aspects of TPACK throughout time. Bibliometric analysis is performed by constructing visualizations using networks, overlays, and densities. Dots or circles that indicate keywords are called nodes in a bibliometric network, while edges, or network nodes, show the connections between nodes in pairs. With Vosviewer software, bibliometric analysis mapping and clustering are complementary, meaning they work best together. A comprehensive image of a bibliometric network's structure can be obtained using this mapping. In addition, clustering provides an overview or insight into bibliometric grouping. Co-occurrence networks are collections of terms connected according to how often they appear together in a given textual unit. A keyword co-occurrence network can map an entire study field by highlighting the most frequently discussed topics within a body of literature and identifying linkages between concepts.

Figure 4 shows a network visualization of co-occurrence, which explains the network or relationship of one term to another in research on TPACK from 2014-2024. The 582 articles indexed by Scopus can be grouped into eight clusters, and the node's colour can be identified for each keyword. Cluster 1, symbolized in red, includes pedagogy, technology, education, technological pedagogical, geogebra, content, mathematics, teachers, and knowledge. Cluster 2, symbolized in green, consists of technological pedagogical content, teacher professional development, e-learning, preservice teacher, and digital competencies. Cluster 3, symbolized in dark blue, consists of terms such as pedagogical knowledge, content knowledge, EFL teachers, and mathematics teachers. Cluster 4, symbolized in yellow, comprises educational technology,

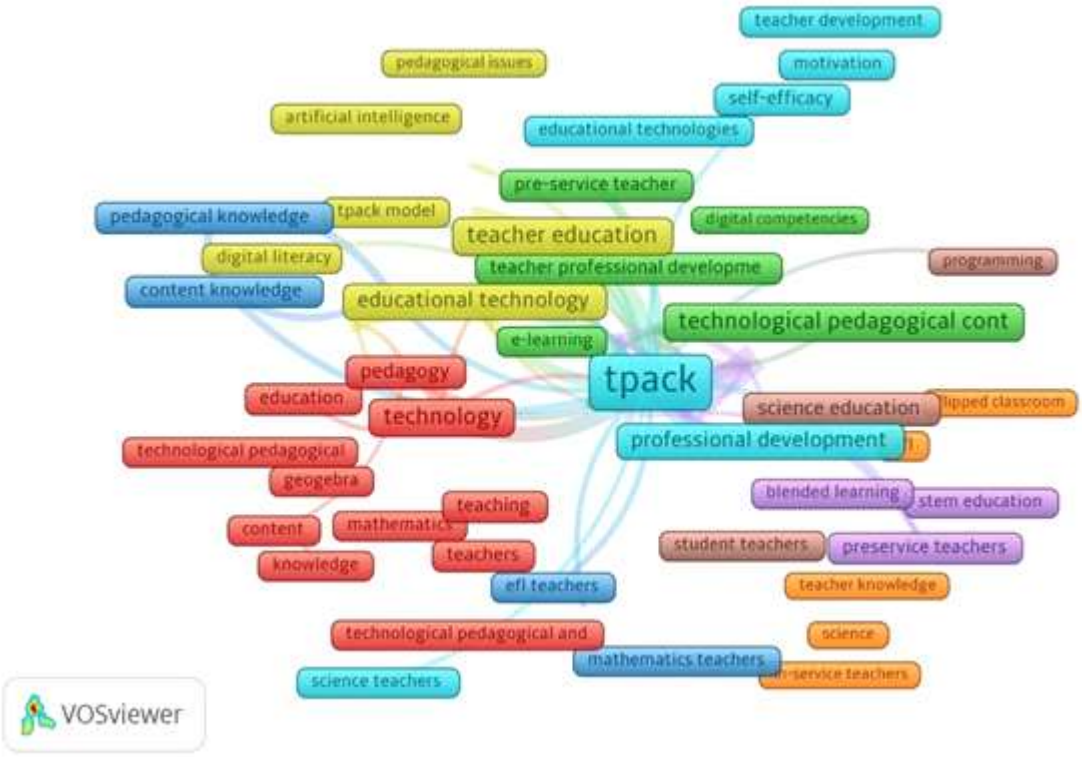

Figure 4. Co-occurrence network visualization

teacher education, digital literacy, the TPACK model, artificial intelligence, and pedagogical issues. Cluster 5, symbolized in purple, consists of blended learning, stem education, and preservice teachers. Cluster 6, symbolized in light blue, consists of TPACK, professional development, science teachers, educational technologies, self-efficacy, motivation, and teacher development. Cluster 7, symbolized in orange, consists of the flipped classrooms, EFL, teacher knowledge, science, and in-service teachers. Cluster 8, symbolized by the colour brown, consists of the term's science education, student teachers, and programming. Based on the co-occurrence network visualization, digital literacy is still open to research that can examine the relationship between digital literacy and TPACK. In Figure 4, the concept of economics teachers and organizational support, especially school support, is not yet visible.

Figure 5. Word cloud

The word cloud generated from the term plus is displayed in Figure 5. More prominent words are those found in literature that are used frequently. In the TPACK literature, the most frequent activity is teaching. Then, there is e-learning, human learning, and engineering education. Several scholars have connected Digital Competence, Digital Literacy, Integration, Teacher Education, and TPACK to provide a framework for teacher digital competency. A study that links technology, teaching experience, technology pedagogy, and online teaching methods during the COVID-19 epidemic was conducted in higher education. Numerous research studies have established a connection between the use of ICT in pedagogy, teacher self-efficacy, and technological pedagogy content understanding. These terms all relate to one another and deal with numerous issues the modern world faces. In Figure 5, there are no words for organizational or school support. This means that research discussing organizational support or school support for teachers' TPACK is still very rare, so it is important to carry out further research.

The collaborative networks among countries in TPACK research

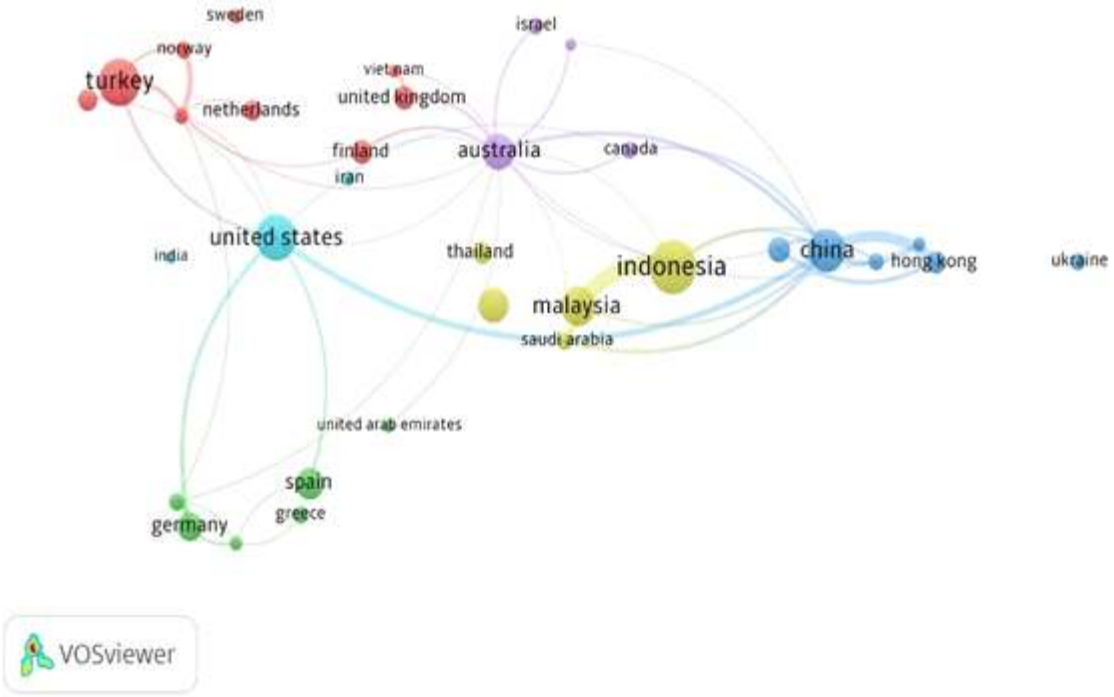

Figure 6. Co-authorship based on countries

Author collaboration is crucial for understanding the trajectory of research in many disciplines because it can inspire academic institutions to develop and broaden their study fields in the future. The intellectual links between scholars from different countries are shown in Figure 6, as well as the nations that have contributed the most citations to TPACK. Multiplicity and diversity of group writings in a field led to the formation of a joint authorship or co-authorship network, which has many similarities with the scientific community and knowledge structure in the academic environment in point of view and this network, the authors as the correlated entities form the global system of knowledge production (Zare-Farashbandi et al.,

2014). We created maps of national co-authorship visualization by analyzing co-authorship between various nations using VOSviewer. Researchers can find potential collaborators and gain insight into current partnerships using country co-authorship maps (Zhao et al., 2020). The dot's diameter represents the total number of publications in a nation. The thickness of the lines and the space between the dots indicate the level of involvement (Kirby, 2023). The degree of a country's ties is determined by the number of articles authored by authors from two or more nations. China, Indonesia, Australia, and the USA are leaders in collaboratives about TPACK topic (Table 5).

Table 5. Top 10 collaboratives countries

From	To	Frequency
China	Australia, Canada, Colombia, France, Hong Kong, Jordan, Korea, Malaysia, New Zealand, Saudi Arabia, Singapore, South Africa, Spain, Ukraine, United Kingdom, USA	38
Indonesia	Australia, China, Hong Kong, Korea Malaysia, New Zealand, Saudi Arabia, Thailand	20
Australia	Canada, Finland, Iran, Israel, New Zealand, Oman, Poland, Saudi Arabia, Singapore, Switzerland, United Arab Emirates, United Kingdom	16
USA	Australia, Belgium, Brazil, Canada, Finland, France, Germany, Iran, Ireland, Japan, Korea, Norway, Spain	16
Malaysia	Bhutan, Estonia, France, Jordan, Norway, Oman, Pakistan, Saudi Arabia, United Arab Emirates, United Kingdom	12
Spain	Andorra, Austria, Costa Rica, Czech Republic, Denmark, France, Germany, Greece, Italy, Portugal, South Africa	12
Germany	Austria, France, Italy, Portugal, Switzerland	9
Turkey	Belgium, Brazil, Norway, United Kingdom, USA	9
United Kingdom	Israel, Mauritius, New Zealand, Oman, Poland, Saudi Arabia, Sweden, United Arab Emirates	8
Greece	Austria, Czech Republic, Denmark, Portugal, United Arab Emirates	5

■ CONCLUSION

The primary goal of this research is to determine the most pertinent keywords, the most prestigious journals and productive writers, the subjects that academics are most interested in discussing, the trends in upcoming TPACK publications, and international collaboration networks related to TPACK. Through meticulous analysis of a sizable data set over an extended period, our research has significantly advanced our understanding of TPACK. The study's conclusions offer a perceptive outlook for the future and present stimulating prospects for more investigation and analysis in this quickly evolving sector. This article's unique feature is its particular use of scientometric analysis in the study of TPACK. One unique feature of this study is the application of these analytical techniques to

country collaboration in TPACK research, map research settings, and detect patterns in keywords and notable contributors. This study spans a sizable amount of time, from March 2024 to 2014, making it possible to see changes and adjustments in the research focus over time and to get a complete picture of how the field has developed. Using the Scopus database, an exceptionally dependable source of scientific papers, this study data analysis gains credibility and reliability.

This study's primary focus is TPACK. Based on the analysis results, the keywords that appeared most frequently in publications were TPACK (194 articles), followed by technology pedagogy content knowledge (91 articles) and technology integration (48 articles). The Australian Journal of Educational Technology is the journal that publishes the most articles on the TPACK theme (24 articles) and also has the highest number of local citations. Chai is number one on the list of authors with the highest impact. The most influential publication in terms of global citations (Table 4) is an article by Falloon (2020) published in 2020 in Educational Technology Research and Development. Based on the co-occurrence network visualization, digital literacy is still open to research that can examine the relationship between digital literacy and TPACK. The concept of economics teachers and organizational support, especially school support, is not yet visible. The degree of a country's ties is determined by the number of articles authored by authors from two or more nations. China, Indonesia, Australia, and the USA are leaders in collaboratives about TPACK topic.

By employing co-occurring terms in the title and abstract, future researchers might also gain insight into potential study questions. One of the research's shortcomings is that it solely relies on the Scopus database to locate pertinent publications. Future research initiatives could use additional academic databases, such as Web of Science (WoS) and PubMed, as multiple evaluations to provide a more comprehensive qualitative and quantitative assessment of TPACK. Within its scope, the technique's limitations exceed its advantages; doing a more in-depth assessment of a research issue without first looking into specific methodologies and models presents a hurdle. Because of this, the scientometric approach places greater emphasis on the product than the article's substance.

■ REFERENCES

Al-Emran, M., Mezhuyev, V., & Kamaludin, A. (2018). Technology acceptance model in M-learning context: A systematic review. *Computers and Education*, *125*(August 2017), 389–412. https://doi.org/10.1016/j.compedu.2018.06.008

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. https://doi.org/10.1111/bjet.12565

Batista-Canino, R. M., Santana-Hernández, L., & Medina-Brito, P. (2023). A scientometric analysis on entrepreneurial intention literature: Delving deeper into local citation. *Heliyon*, *9*(2). https://doi.org/10.1016/j.heliyon.2023.e13046

Brianza, E., Schmid, M., Tondeur, J., & Petko, D. (2024). The digital silver lining of the pandemic: The impact on preservice teachers' technological knowledge and beliefs. *Education and Information Technologies*, *29*(2), 1591–1616. https://doi.org/10.1007/s10639-023-11801-w

Deng, F., Chai, C. S., So, H.-J., Qian, Y., & Chen, L. (2017). Examining the validity of the technological pedagogical content knowledge (TPACK) framework for preservice chemistry teachers. In

Australasian Journal of Educational Technology (Issue 3).

Dewi, N. R., Rusilowati, A., Saptono, S., Haryani, S., Wiyanto, W., Ridlo, S., Listiaji, P., & Atunnisa, R. (2021). Technological, Pedagogical, Content Knowledge (TPACK) Research Trends: A systematic literature review of publications between 2010 - 2020. *Journal of Turkish Science Education*, *18*(4), 589–604. https://doi.org/10.36681/tused.2021.92

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*, *68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Hakam, L. I., Ahman, E., Disman, D., Mulyadi, H., & Hakam, D. F. (2023). Research/ : A Scientometric Analysis. *Economies*, *11*, 269. https://doi.org/https://doi.org/10.3390/economies11110269 Academic

Harzing, A. W., & Alakangas, S. (2016). Google scholar, scopus and the web of science: a longitudinal and cross-disciplinary comparison. *Scientometrics*, *106*(2), 787–804. https://doi.org/10.1007/s11192-015-1798-9

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(46), 16569–16572. https://doi.org/10.1073/pnas.0507655102

Jang, J., Ko, Y., Shin, W. S., & Han, I. (2021). Augmented reality and virtual reality for learning: an examination using an extended technology acceptance model. *IEEE Access*, *9*, 6798–6809. https://doi.org/10.1109/ACCESS.2020.3048708

Ke, F., & Hsu, Y. C. (2015). Mobile augmented-reality artifact creation as a component of mobile computer-supported collaborative learning. *Internet and Higher Education*, *26*, 33–41. https://doi.org/10.1016/j.iheduc.2015.04.003

Kirby, A. (2023). Exploratory Bibliometrics: Using VOSviewer as a Preliminary Research Tool. *Publications*, *11*(1), 1–14. https://doi.org/10.3390/publications11010010

Lee, H., Chang, C., & Chung, C. (2021). Research on design thinking and tpack of physical education pre-service teachers. *29th International Conference on Computers in Education Conference, ICCE 2021 - Proceedings*, *2*, 9–16. https://scholar.lib.ntnu.edu.tw/en/publications/research-on-design-thinking-and-tpack-of-physical-education-pre-s

Lee, H. Y., Chung, C. Y., & Wei, G. (2022). Research on technological pedagogical and content knowledge: a bibliometric analysis from 2011 to 2020. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.765233

Leitão, J., Pereira, D., Gonçalves, Â., & Oliveira, T. (2023). Digitalizing the pillars of Hybrid Civic Universities: A bibliometric analysis and new taxonomy proposal. *Journal of Open Innovation: Technology, Market, and Complexity*, *9*(1), 100026. https://doi.org/10.1016/j.joitmc.2023.100026

Marlina, R., Hamdani, H., & Oktavianty, E. (2023). Research trends in technological pedagogical content knowledge (TPACK) reflective practitioners in higher education. *AIP Conference Proceedings*. https://pubs.aip.org/aip/acp/article/2751/1/060004/2896228

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054.

Mukminin, A., Habibi, A., & Fridiyanto. (2020). Technology in the classroom: Efl teachers'technological pedagogical and content knowledge. *Informatologia*, *53*(1–2), 24–36. https://doi.org/10.32914/i.53.1-2.3

Nightingale, J. M., & Marshall, G. (2012). Citation analysis as a measure of article quality, journal influence and individual researcher performance. *Radiography*, *18*(2), 60–67. https://doi.org/10.1016/j.radi.2011.10.044

Nousiainen, T., Kangas, M., Rikala, J., & Vesisenaho, M. (2018). Teacher competencies in game-based pedagogy. *Teaching and Teacher Education*, *74*, 85–97. https://doi.org/10.1016/j.tate.2018.04.012

Patra, S. K., & Muchie, M. (2021). Scientific and technical productivity of african countries: what scopus and WIPO Patentscope Data Tell Us? *Journal of Scientometric Research*, *10*(3), 355–365. https://doi.org/10.5530/jscires.10.3.53

Pollack, J., & Adler, D. (2015). Emergent trends and passing fads in project management research: A scientometric analysis of changes in the field. *International Journal of Project Management*, *33*(1), 236–248. https://doi.org/10.1016/j.ijproman.2014.04.011

Sahni, J. (2019). Does blended learning enhance student engagement? evidence from higher education. *Journal of E-Learning and Higher Education*, *2019*(January), 1–14. https://doi.org/10.5171/2019.121518

Scherer, R., Tondeur, J., Siddiq, F., & Baran, E. (2018). The importance of attitudes toward technology for pre-service teachers' technological, pedagogical, and content knowledge: Comparing structural equation modeling approaches. *Computers in Human Behavior*, *80*, 67–80. https://doi.org/10.1016/j.chb.2017.11.003

Schmid, M., Brianza, E., & Petko, D. (2020). Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model. *Computers and Education*, *157*. https://doi.org/10.1016/j.compedu.2020.103967

Sofwan, M., Yaakob, M. F. M., & Habibi, A. (2024). Technological, pedagogical, and content knowledge for technology integration: a systematic literature review. *International Journal of Evaluation and Research in Education* , *13*(1), 212–222. https://doi.org/10.11591/ijere.v13i1.26643

Su, J. (2023). Preservice teachers ' technological pedagogical content knowledge development/ : A bibliometric review. *January*, 1–11. https://doi.org/10.3389/feduc.2022.1033895

Tseng, J. J., Chai, C. S., Tan, L., & Park, M. (2020). A critical review of research on technological pedagogical and content knowledge (TPACK) in language teaching. *Computer Assisted Language Learning*, *35*(4), 948–971. https://doi.org/10.1080/09588221.2020.1868531

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. In *Australasian Journal of Educational Technology* (Issue 3).

Voogt, J., & McKenney, S. (2017). TPACK in teacher education: are we preparing teachers to use technology for early literacy? *Technology, Pedagogy and Education*, *26*(1), 69–83. https://doi.org/

10.1080/1475939X.2016.1174730

Webb, M., Davis, N., Bell, T., Katz, Y. J., Reynolds, N., Chambers, D. P., Sys, M. M., & Webb, M. (2017). Computer science in K-12 school curricula of the 2lst century/ : Why , what and when/ ? Content courtesy of Springer Nature , terms of use apply . Rights reserved . Content courtesy of Springer Nature , terms of use apply . Rights reserved . 445–468. https://doi.org/10.1007/s10639-016-9493-x

Wong, L. H., Chai, C. S., Zhang, X., & King, R. B. (2015). Employing the TPACK framework for researcher-teacher co-design of a mobile-assisted seamless language learning environment. *IEEE Transactions on Learning Technologies*, *8*(1), 31–42. https://doi.org/10.1109/TLT.2014.2354038

Yalcinkaya, M., & Singh, V. (2015). Patterns and trends in Building Information Modeling (BIM) research: A Latent Semantic Analysis. *Automation in Construction*, *59*, 68–80. https://doi.org/10.1016/j.autcon.2015.07.012

Zare-Farashbandi, F., Geraei, E., & Siamaki, S. (2014). Study of co-authorship network of papers in the journal of research in medical sciences using social network analysis. *Journal of Research in Medical Sciences*, *19*(1), 41–46.

Zhao, Y., Zhang, X., Song, Z., Wei, D., Wang, H., Chen, W., Sun, G., Ma, W., & Chen, K. (2020). Bibliometric analysis of ATAC-Seq and Its Use in Cancer Biology via Nucleic Acid Detection. *Frontiers in Medicine*, *7*(November), 1–11. https://doi.org/10.3389/fmed.2020.584728