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EDITED BY
Stefinee Pinnegar,
Brigham Young University,
United States

REVIEWED BY
Mario Mäeots,
University of Tartu,
Estonia

*CORRESPONDENCE
Jiahong Su
maggiesu@connect.hku.hk

SPECIALTY SECTION
This article was submitted to
Teacher Education,
a section of the journal
Frontiers in Education

RECEIVED 01 September 2022
ACCEPTED 24 November 2022
PUBLISHED 04 January 2023

CITATION
Su J (2023) Preservice teachers'
technological pedagogical content
knowledge development: A bibliometric
review.
Front. Educ. 7:1033895.
doi: 10.3389/feduc.2022.1033895

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Preservice teachers' technological pedagogical content knowledge development: A bibliometric review

Jiahong Su*

Faculty of Education, The University of Hong Kong, Pokfulam, Hong Kong SAR, China

Technological pedagogical content knowledge (TPACK) has become an emerging topic in teacher education research. This review aims to analyze the global trends of the research on preservice teachers' technological pedagogical content knowledge (TPACK) development. The bibliometric approach examines preservice teachers' TPACK by identifying the most cited publications, journals, authors, funding agencies, and keywords used in the eligible studies (N=114). The results show that preservice teachers' TPACK research began in 2007 and the scientific community's interest in this subject has been irregular. This study presents a global perspective on preservice teachers' TPACK and provides researchers with future directions.

KEYWORDS

technological pedagogical content knowledge (TPACK), potential research topics, preservice teachers, Preservice Teacher Education, bibliometric analysis

Introduction

An influential theoretical framework for teaching with technology is called TPACK (technological pedagogical and content knowledge). The TPACK framework builds on Lee Shulman's construct of pedagogical content knowledge (PCK) to include technological knowledge (Koehler and Mishra, 2009, p. 60). TPACK framework includes several knowledge components, such as technological knowledge (TK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and pedagogical content knowledge (PCK) (Graham, 2011).

Recently, many researchers adopted the TPACK framework in teacher education research (e.g., Lachner et al., 2021; Lai et al., 2022; Wollmann and Lange-Schubert, 2022), especially in preservice teacher settings (e.g., Luo et al., 2022; Zhou et al., 2022). However, although a number of to several reviews of TPACK literature exist (e.g., Rosenberg and Koehler, 2015; Wang et al., 2018; Yeh et al., 2021), there are apparently no studies discussing preservice teachers' technological pedagogical content knowledge (TPACK) development using bibliometric analysis. Therefore, this review paper aims to present a thorough

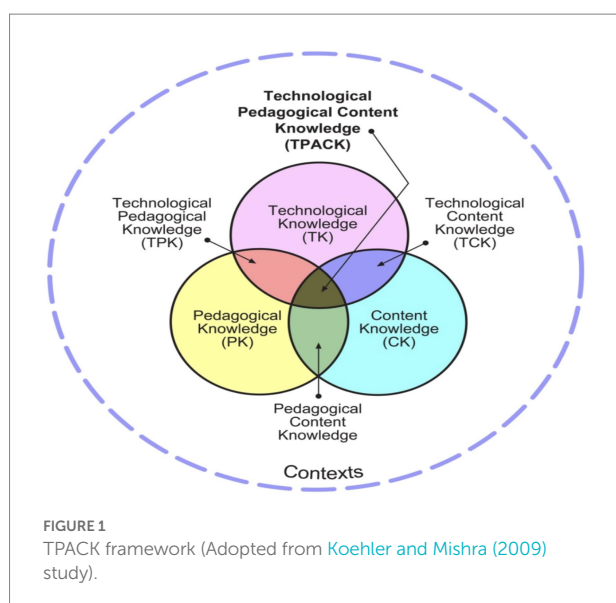
bibliometric analysis from Scopus databases of scientific publications, by (1) identifying productive publication sources, authors, journals, affiliations, and countries in the field of TPACK research targeting preservice teachers; (2) helping researchers to find collaborations, journals, and funding agencies; (3) providing recommendations for future plans for technological pedagogical content knowledge (TPACK) research focusing on preservice teachers.

What is TPACK?

The term “TPACK” refers to “the synthesized form of knowledge to integrate ICT/educational technology into classroom teaching and learning” (Chai et al., 2013, 2016). The technological pedagogical content knowledge (TPACK) framework, which is based on Shulman (1986, 1987) descriptions of pedagogical content knowledge (PCK), explains how teachers’ understanding of educational technologies and PCK interact with each other to achieve effective teaching using technology.

TPACK constructs

The three main components of TPACK are technological knowledge (TK), pedagogical knowledge (CK), and content knowledge (CK) (Koehler and Mishra, 2009), as shown in Figure 1. Pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical content knowledge (TPK), and TPACK are products of the interplay among these three fundamental types of knowledge.



Bibliometric analysis

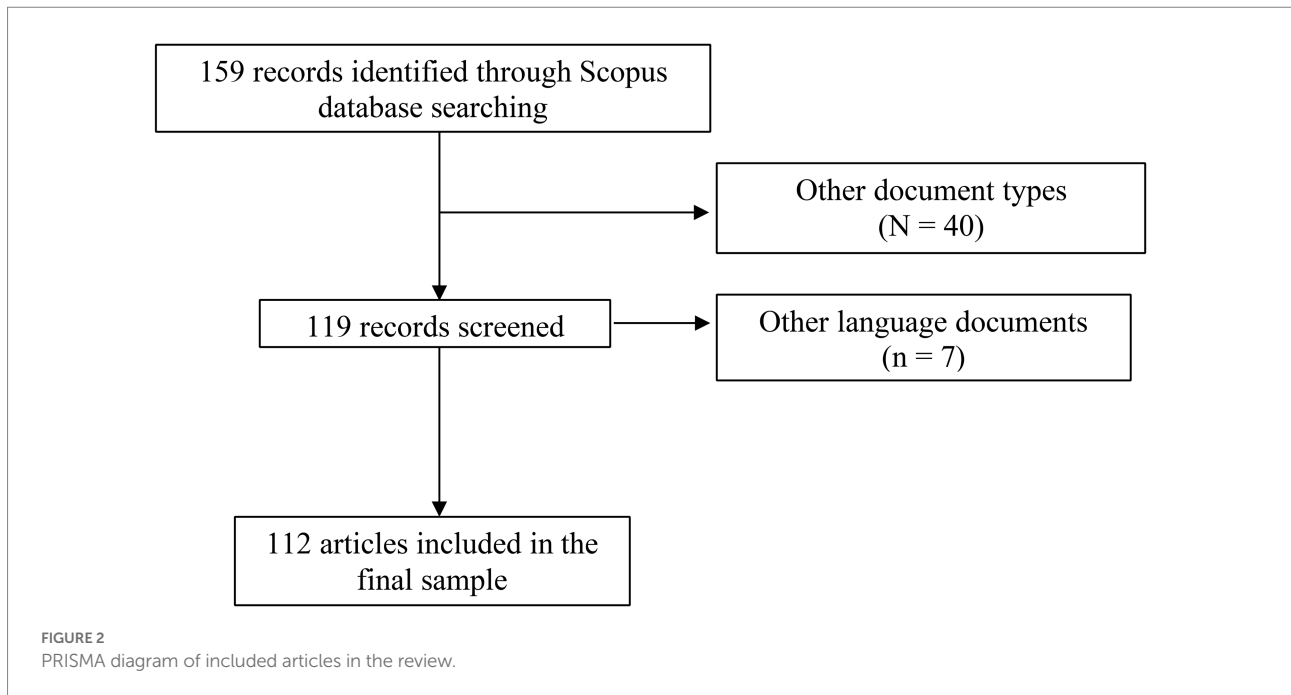
A methodology known as “bibliometric analysis” is an approach that employs a number of to several quantitative techniques to measure, track, and analyze scholarly literature (Roemer and Borhardt, 2015). The bibliometric analysis offers “quantitative confirmation of subjectively derived categories in published reviews as well as for exploring the research landscape and identifying the categories” (Zupic and Cater, 2015; Hasumi and Chiu, 2022). In addition, it identifies the authors’ publications, the top journals, research collaborations, and the most popular keywords used (Aria and Cuccurullo, 2017; Xue and He, 2021). Most educational studies used VOSviewer to analyze and conduct a bibliometric analysis (e.g., Gillani et al., 2022; Su et al., 2022). Therefore, VOSviewer software was used for data analyses in this study.

In recent years, bibliometric analysis has become popular in educational research (e.g., Rojas-Sánchez et al., 2022; Su et al., 2022; Zhang et al., 2022). Researchers use bibliometric analysis for several purposes, including developing trends in article and journal performance, collaboration patterns, and the intellectual framework to examine of a specific domain in the existing literature (Djeki et al., 2022; Su et al., 2022). In addition, bibliometric analysis can be found in the scientific literature. For example, a recent study by Su et al. (2022) investigated ECE during the COVID-19 pandemic using bibliometric methods by analyzing a total of 507 articles from the web of science (WOS) and Scopus databases between 2020 and 2022. This article presented the research landscape of the top research publications, authors, institutions, countries, and keywords. Since the characteristics of the most widely referenced works in the field of preservice teachers’ technological pedagogical content knowledge (TPACK) development have received minimal attention in academia, this study seeks to investigate the research trends of the most cited articles about preservice teachers’ technological pedagogical content knowledge (TPACK) development published in Social Science Citation Index (SSCI) journals.

Methods and data

Article selection process

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendation statement (Moher et al., 2009) was followed in this bibliometric review. Scholarly literature on this topic was searched on the Scopus database. Numerous review articles have highlighted that the Scopus database is suitable for bibliometric analysis in the field of education (e.g., Ghani et al., 2022; Supriadi et al., 2022). It is one of the most widely used databases in various scientific fields, and is frequently used for literature searches (Singh et al., 2021).



We formulated a search string based on our understanding of and knowledge of the TPACK domain and referred to related TPACK education search strings used in other studies, such as Zou et al. (2022). The search terms include “technological pedagogical content knowledge” AND “TPACK” OR “TPCK” AND preservice teacher* OR pre-service teacher. Content analysis of keywords was used as a method of analysis within this study. The search was limited to publications written in English and journal articles. Therefore, a total of 159 articles were retrieved.

Exclusion criteria

The corresponding databases applied two exclusion criteria (EC) to exclude irrelevant literature. First, to ensure the quality of this article, only journal articles were included in this study, disregarding other document types, such as books, conference proceedings, and book series ($n = 40$). Second, articles written in other languages, such as Turkish, Chinese, French, and Spanish, were excluded ($n = 7$).

Analysis

Having applied the criteria above, 112 studies were selected. Figure 2 below provides an overview of our search protocol. The preliminary analysis of articles highlighted the annual frequency of publications, representative journals, countries/regions, institutions, and the most commonly researched keywords. Next, the study of keyword co-occurrence was carried out using VOSviewer.

Research questions

The five research questions (RQs) in our bibliometric analysis focusing on the research on the development of preservice teachers’ technological pedagogical content knowledge (TPACK) from 2007 to 2022 are as follows:

RQ1: What was the annual trend of preservice teachers’ TPACK research?

RQ2: Which representative journals, journals, countries/regions, institutions, and funding agencies were the major preservice teachers’ TPACK research contributors?

RQ3: Who were the most productive researchers for preservice teachers’ TPACK research?

RQ4: In which research areas were the issue of the development of preservice teachers’ TPACK addressed?

RQ5: What were the most cited keywords of preservice teachers’ TPACK research?

Results

RQ1: What was the annual trend of preservice teachers’ TPACK research?

Figure 3 shows the annual counts of research on the development of preservice teachers’ technological pedagogical content knowledge (TPACK) from 2007 to 2022. A total of 114 eligible articles have been found in the Scopus database. 2021 was found to be the most published year (Table 1).

RQ2: Which representative journals, journals, countries/regions, institutions, and funding agencies were the major preservice teachers’ TPACK research contributors?

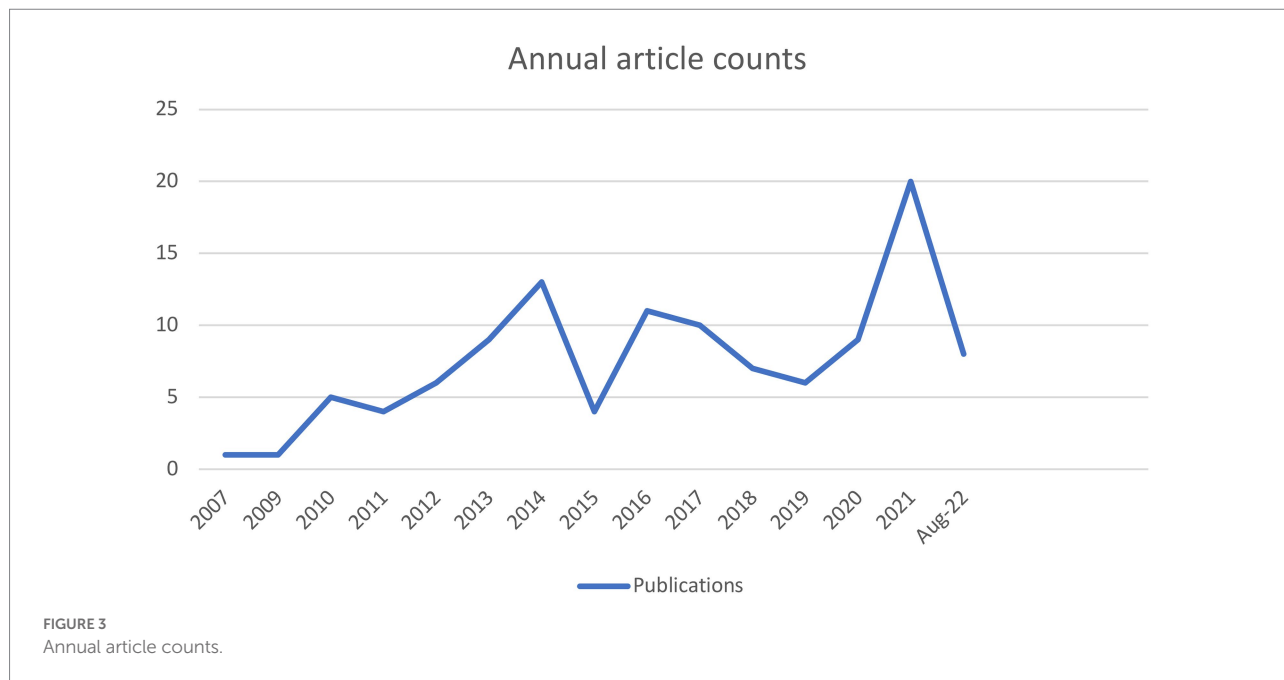


FIGURE 3 Annual article counts.

TABLE 1 Annual article counts.

Year	Publications
2007	1
2009	1
2010	5
2011	4
2012	6
2013	9
2014	13
2015	4
2016	11
2017	10
2018	7
2019	6
2020	9
2021	20
2022	8

Representative journals

The number of citations of a journal article’s publication indicates influential research (Tsay, 2008). Three top representative articles, which focus on online professional development, mentorship, and instrument development, are shown in Table 2.

Table 2 indicated that the most cited journal articles published in Scopus were from the renowned researchers in this field. For example, the article.

“Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers” by Schmidt et al. (2009) received 696 citations in Scopus.

Top journals

A total of 72 journals have published research on developing preservice teachers’ technological pedagogical content knowledge (TPACK) from Scopus databases. In addition, six journals published more than five articles on this topic, such as Computers & Education, Journal of Research on Technology in Education, Australasian Journal of Educational Technology, Journal of Digital Learning in Teacher Education, British Journal of Educational Technology, and Journal of Educational Computing Research (Table 3).

Countries/regions

In total, 25 countries/regions produced research on developing preservice teachers’ technological pedagogical content knowledge (TPACK) from the Scopus database. However, six countries published more than seven articles from the Scopus database, including the United States, Turkey, Australia, Hong Kong, Taiwan, and Singapore. The USA contributed 43 (42%) publications. These findings demonstrate that the USA is more interested in this topic (Table 4).

Institutions

108 institutions have contributed to 114 publications about developing preservice teachers’ technological pedagogical content knowledge (TPACK) in Scopus. The Scopus database shows that the most contributive institutions were Nanyang Technological University (7 articles), The Chinese University of Hong Kong (5

TABLE 2 The most cited publications for TPACK in preservice teacher research.

Rank	The representative articles	Authors	Source	Keywords	Scopus citation
1	Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers	Schmidt, D. A.; Baran, E.; Thompson, A. D.; Mishra, P.; Koehler, M.J.; Shin, T. S.	Journal of Research on Technology in Education	Instrument development; Preservice teacher; TPACK	696
2	Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK)	Chai, C. S.; Koh, J. H.L.; Tsai, C. C.	Educational Technology and Society	ICT; Preservice teacher education; TPACK	283
3	Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants	Polly, D.; Mims, C.; Shepherd, C. E.; Inan, F.	Teaching and Teacher Education	Mentorship; Professional development; Teacher education; Technology integration	177

TABLE 3 Most contributing journals.

Journal	Number	Citation
Computers & Education	9	378
Journal of Research on Technology in Education	8	1,054
Australasian Journal of Educational Technology	7	181
Journal of Digital Learning in Teacher Education	7	217
British Journal of Educational Technology	6	99
Journal of Educational Computing Research	5	100

TABLE 4 Countries/regions.

Countries/regions	Publications
USA	43
Turkey	29
Australia	8
Hong Kong	8
Taiwan	8
Singapore	7

TABLE 5 Institutions.

Institutions	Publications
Nanyang Technological University	7
The Chinese University of Hong Kong	5
Middle East Technical University	5
Selçuk Üniversitesi	5

articles), Middle East Technical University (5 articles), and Selçuk Üniversitesi (5 articles), as shown in Table 5.

Funding agencies

46 funding agencies showed interest in investing in research on developing preservice teachers' technological

pedagogical content knowledge (TPACK) in Scopus. Three funding agencies funded the most research projects on this research topic, namely the National Science Foundation (United States), the Ministry of Science and Technology (Taiwan), and the National Taiwan Normal University (Taiwan), as shown in Table 6. Research on developing preservice teachers' technological pedagogical content knowledge (TPACK) garners more attention in Taiwan.

RQ3: Who were the most productive researchers for preservice teachers' TPACK research?

The most productive authors with their affiliated institutions and countries in research on the development of preservice teachers' technological pedagogical content knowledge (TPACK) are shown in Table 7. This can assist researchers in finding appropriate collaborators and institutions for their research. The most productive researchers on this topic are Chai, C.S. (9 publications), Koh, J.H.L. (5 publications), Karchmer-Klein, R. (4 publications), and Mouza, C. (4 publications).

RQ4: In which research areas were the issue of the development of preservice teachers' technological pedagogical content knowledge (TPACK) addressed?

According to the Scopus database, this topic is the most frequently discussed in the field of social sciences, followed by Computer Science, Art and Humanities, and Engineering, as shown in Table 8.

RQ5: What were the most cited keywords of preservice teachers' TPACK research?

TABLE 6 Funding agencies.

Funding sponsor	Countries	Articles	Authors	Journal
National Science Foundation	USA	Using Live Dual Modeling to Help Preservice Teachers Develop TPACK	Lu, L.; Lei, J.	Journal of Digital Learning in Teacher Education
		A virtual internship for developing technological pedagogical content knowledge	Oner, D.	Australasian Journal of Educational Technology
Ministry of Science and Technology, Taiwan	Taiwan	Fostering design-oriented collective reflection among preservice teachers through principle-based knowledge building activities	Hong, H. Y.; Lin, P. Y.; Chai, C. S.; Hung, G. T.; Zhang, Y.	Computers & Education
		Development of an instrument for exploring preservice technology teachers' maker-based technological pedagogical content knowledge	Ku, C. J.; Loh, W. L. L.; Lin, K. Y.; John Williams, P.	British Journal of Educational Technology
National Taiwan Normal University	Taiwan	Exploring the structure of TPACK with video-embedded and discipline-focused assessments	Yeh, Y. F.; Hsu, Y. S.; Wu, H. K.; Chien, S. P.	Computers & Education
		Development of an instrument for exploring preservice technology teachers' maker-based technological pedagogical content knowledge	Ku, C. J.; Loh, W. L. L.; Lin, K. Y.; John Williams, P.	British Journal of Educational Technology

TABLE 7 The authors who have the most contribution to preservice teachers' TPACK research.

Authors	Institutions	Country/Regions	Number of publications
Chai, C.S.	The Chinese University of Hong Kong	Hong Kong	9
Koh, J.H.L.	University of Otago	New Zealand	5
Karchmer-Klein, R.	University of Delaware	United States	4
Mouza, C.	University of Delaware	United States	4

TABLE 8 Research areas.

Research Areas	Publications
Social Sciences	116
Computer Science	42
Art and Humanities	7
Engineering	7

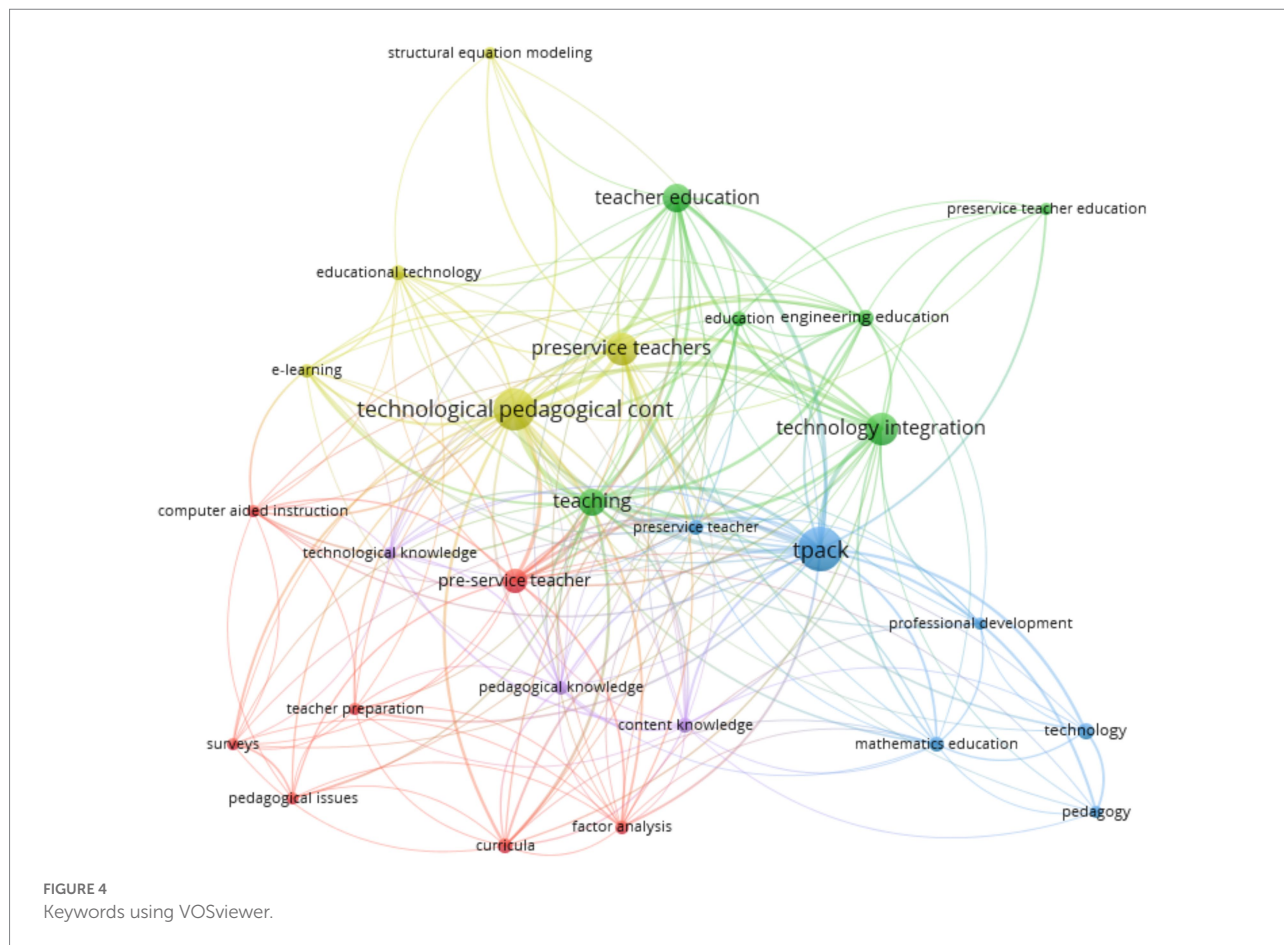
TABLE 9 Keywords.

Keywords	Publications
TPACK	47
Technological pedagogical content knowledge	38
Technology Integration	29
Preservice Teachers	24
Teacher education	17
Teaching	13
Pre-service Teacher	9
Engineering Education	6
Mathematics Education	6
Technology	6
Content Knowledge	5
Factor Analysis	5
Pedagogical Issue	5
Preservice Teacher Education	5
Structural Equation Modeling	5

The keywords help researchers find the most relevant information (Guo et al., 2019). For example before 15 keywords were shown more than five times in studies on the development of preservice teachers' technological pedagogical content knowledge (TPACK) in the Scopus database, including 'TPACK', 'technological pedagogical content knowledge', 'Technology Integration', 'Preservice Teachers', 'Teacher education', 'Teaching', 'Pre-service Teacher', 'Engineering Education', 'Mathematics Education', 'Technology', 'Content Knowledge', 'Factor Analysis', 'Pedagogical Issue', 'Preservice Teacher Education', and 'Structural Equation Modeling', as shown in Table 9. We found that factor analysis (FA) and structural equation modeling (SEM) were important analysis methods in research on the development of preservice teachers' technological pedagogical content knowledge (TPACK), as evidenced by how it was both used five times as keywords. For example, Chai et al. (2019) used the SEM model

as a data analysis method. These two analysis methods (i.e., FA and SEM) are appropriate for research on TPACK in preservice teachers.

We used the VOSviewer to perform keyword co-occurrence analysis. Twenty-seven keywords were shown more than five times in the Scopus database, as shown in Figure 4. TPACK is the



leading keyword and has stronger links with tpack, technology integration, and pre-service teachers. Figure 4 shows the detection of relevant main topics, participants, and data analysis methods used. Most of the research on preservice teachers' TPACK was quantitative such as factor analysis and structural equation modeling. The majority of these studies used a survey design (5 times). For example, Schmidt et al. (2009) used a surveys to assess preservice teachers' self-assessment of the TPACK framework, including technological knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK).

Co-occurrence

Keyword clustering

To better understand the significance of various keywords, Table 10 shows the keyword clustering. According to the measurements of keyword centrality, Technological pedagogical content knowledge (TPACK) was the keyword with the highest influence. It was found that preservice teachers' TPACK surveys were also used in other fields, such as engineering and

Mathematics education (e.g., Larkin et al., 2012; Tokmak et al., 2013; Putro et al., 2020). For example, Larkin et al. (2012) used the TPACK framework, which includes TPK, TK, TPCK, PCK, and TCK, to assess preservice teachers' ability to teach Mathematics. Agyei and Voogt (2015) adopted a TPACK survey to assess preservice teachers' perceived development in their TPACK. "Tpack" was the most frequently used keyword in this research, followed by "Technological pedagogical content knowledge". Third, some studies the proposed model using SEM and FA analysis (e.g., Dong et al., 2015; Joo et al., 2018; Kabacki Yurdakul, 2018).

SEM is a method used to establish associations between a scale and the independent variables hypothesized to influence the scale. For example, "A structural equation model was generated using AMOS 16.0 software to test whether digital nativity was a determinant of TPACK-deep" (Kabacki Yurdakul, 2018). Lastly, several studies used surveys to assess teachers' perceptions of TPACK constructs (e.g., Jamieson-Proctor et al., 2010; Dong et al., 2015; Gabriele et al., 2019). For example, Dong et al. (2015) used surveys to "measure teachers' perceptions concerning the extent to which they agreed or disagreed with statements related to the seven TPACK constructs and their beliefs concerning the constructivism and design deposition" (p. 161).

TABLE 10 Keyword clustering.

	Keywords	Occurrences	Total link strength
<i>Clusters 1 TPACK</i>	Tpack	56	125
	Technological pedagogical content knowledge	52	153
	Content knowledge	7	33
	Pedagogical knowledge	6	31
	Technological knowledge	5	24
<i>Cluster 2 preservice teacher</i>	Preservice teachers	30	66
	Preservice teacher	7	26
	Pre-service teacher	17	67
	Preservice teacher education	5	10
	Teacher preparation	5	16
<i>Cluster 3 education</i>	Education	7	33
	Engineering education	8	41
	Teacher education	23	71
	Mathematics education	7	24
	Professional development	5	12
<i>Cluster 4 instruction</i>	Computer aided instruction	5	22
	Curricula	7	31
	Pedagogical issue	5	14
	Pedagogy	5	14
	Teaching	22	101
<i>Cluster 5 educational technology</i>	Technology integration	31	79
	e-learning	6	26
	Educational technology	7	21
	Technology	8	19
<i>Cluster 5 data analysis methods</i>	Structural equation modeling	5	9
	Factor analysis	6	25
<i>Cluster 6 data collection</i>	Surveys	5	17

Dong et al. (2015) used the SEM model to examine whether or not to predict TPACK. Results show that the primary forms of knowledge (CK, PK, and TK) predict the secondary forms of knowledge (TPK, TCK, and PCK) and that TCK and TPK predict TPACK.

Discussion and conclusion

This study analyzes a selection of recent articles with the help of the Scopus database to identify research trends in studies centering on preservice teachers' TPACK. The research publications were examined using the bibliometric technique in terms of publications, prolific countries/regions, institutions, funding agencies, journals, publishers, and keyword distributions. These results help researchers find a potential research topic, collaborators, institutions, and funding agencies.

This review of research is the first bibliometric review focusing on the literature on preservice teachers' TPACK. It seeks to shed light on the trends in the publication of studies on the development of preservice teachers' TPACK through bibliometric analysis of 112 Scopus-indexed journal articles published between 2007 and 2022. Recently, more and more literature reviews on TPACK have been published (e.g., Wang et al., 2018; Yeh et al., 2021; Tseng

et al., 2022). This trend is consistent with findings reported by Lee et al. (2022).

However, the research trends of preservice teachers' TPACK were not a focus of these articles. It was discovered that the majority of literature was authored in developed societies: the United States (43 publications), Turkey (29 publications), Australia (8 publications), Hong Kong (8 publications), and Singapore (7 publications). This result was consistent with findings reported by Irwanto (2021) and Dewi et al. (2021). Possible factors influencing developing countries' interest in preservice teachers' TPACK include research funding, resources, and social environments. Studies on preservice teachers' TPACK are more frequently featured in high-quality educational journals, including *Computers & Education* (9 publications, 378 citations), *British Journal of Educational Technology* (6 publications, 99 citations), *Journal of Research on Technology in Education* (8 publications, 1,054 citation).

White and McCain (1998) mentioned that "a strength of the bibliometric analysis is its capacity to identify key authors and texts through empirical analysis of the literature" (p. 327). This review's citation and co-citation analyses identified which researchers most contributed to preservice teachers' TPACK research: Chai, Koh, Karchmer-Klein, and Mouza. The authors above are from developed countries/regions: Hong Kong, New Zealand, and the United States.

Potential research topics

Self-regulated learning. Only three studies focus on self-regulated learning integrated technological pedagogical content knowledge (TPCK) context (Kramarski and Michalsky, 2010; Angeli et al., 2015; Huang et al., 2021). Kramarski and Michalsky (2010) used the motivated strategies for learning questionnaire (MSLQ) to assess preservice teachers' self-reported SRL components, including cognition, metacognition, and motivation. For example, "When I read material for the course, I say the words over and over to myself to help me remember," "When I study for this course, I put important ideas into my own words," and "I outline the chapters in my task to help me study" (Kramarski and Michalsky, 2010, p. 441). Results show that preservice teachers' capacity to evaluate their learning processes may be improved by adopting the improved self-questioning technique. Most studies examining "cognition," "metacognition," and "motivation" in technology education underscored the significance of these SRL components (e.g., Barak, 2010; Azevedo and Alevin, 2013). Therefore, the first potential research topic is the self-regulated learning integrated technological pedagogical content knowledge (TPCK) context.

Teachers' attitudes toward technology. Only one study focuses on teachers' attitudes towards technology (Banas, 2010). Banas (2010) designed TPCK-related instruction and assessed teachers' attitudes toward technology. Results show that more than half had positive feelings about integrating technology into instruction. This finding, nonetheless, was not corroborated by other studies as the majority of them examined teachers' perceptions of technology without referring to the TPACK framework (e.g., Albirini, 2006; Yildiz Durak, 2021). Therefore, teachers' attitudes towards technology in the TPACK context is the second potential research topic.

Contributions

This review study contributes to the TPACK field in several aspects. To begin with, it offers researchers a comprehensive overview of the research status and development of preservice teachers' technological pedagogical content knowledge. Second, it assists researchers in identifying the authors, institutions, and

countries/regions with the most potential to develop this research topic and find suitable collaborators. Third, the keywords identified help researchers locate the most essential information and understand the research hotspots in this field. Fourth, the most influential journals in this field have been pinpointed for researchers and research students.

Limitations

This review study has three limitations. First, a meta-analysis, which is not included in this study, is required to gain a deeper understanding of research on preservice teachers' TPACK. Second, two keywords (e.g., "TPACK" and "TPCK") are arguably not distinctive enough to narrow down research topics. Lastly, the range of data collected was limited since it was only extracted from the Scopus database, but not other databases (e.g., Web of Sciences).

Author contributions

JS contributed to conception and design of the study, organized the database, performed the statistical analysis, writing—original draft preparation, and writing—review and editing.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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