International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 1, February 2024, pp. 212~222
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i1.26643

Technological, pedagogical, and content knowledge for technology integration: a systematic literature review

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Article Info

Article history:

Received Jan 22, 2023
Revised Oct 15, 2023
Accepted Nov 7, 2023

Keywords:

Content
Literature
Pedagogy
Review
Technology

ABSTRACT

Many empirical studies used technological, pedagogical, and content knowledge (TPACK) to evaluate technology integration in education. However, systematic reviews on TPACK, related to technology integration in education are still limited, linked to the TPACK and technology integration issue. Therefore, this systematic literature reviews TPACK-based studies from 2010 to 2022, focusing on three topics: instruments to assess TPACK, TPACK domains' inter-correlation, and TPACK relationships with technology integration. This systematic literature review implemented PRISMA (preferred reporting items for systematic reviews and meta-analyses). The study used Science Direct as a platform for articles' search with three keywords, namely TPACK, preservice teacher; TPCK, preservice teacher; and TPACK, preservice teacher, technology integration. There were 28 articles reviewed. The findings informed 11 articles regarding scales to assess TPACK. There were nine articles reported TPACK domains' intercorrelation and 10 articles informed TPACK relationships with technology integration. This study could significantly contribute to advancing knowledge regarding instruments to assess TPACK, TPACK factors inter-correlation, and TPACK and technology integration.

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1. INTRODUCTION

Technological, pedagogical, and content knowledge (TPACK) was established based on pedagogical content knowledge (PCK) [1]. The combination of pedagogical and content knowledge supports the PCK in the TPACK framework. The primary concept of TPACK is that a teacher's knowledge of technology is diverse, recommending that technology, pedagogy, and content should be balanced. The TPACK framework tries to address the difficulties presented by the new era of teaching and learning with the advancement of technology, especially the internet. Teachers are recommended to promote the integration of technology into their teaching to prepare students for the workforce.

TPACK has been central to research regarding teaching and learning processes and teacher professional development [2]–[4]. TPACK is a mirror extension of Shulman's characterization of the knowledge required to teach specific content, known as PCK or pedagogical content knowledge [5]. PCK characterizes the necessary knowledge to teach specific contents using technology [6]. In short, the TPACK framework explains technological knowledge (TK or technological knowledge, knowledge about some specific tools, software, and hardware), pedagogical knowledge (PK or pedagogical knowledge, how to manage, order, and lead students), and content knowledge (CK or content knowledge, regarding teaching materials). The

second level comprises technological pedagogical knowledge (TPK, the relationship between technologies and pedagogical knowledge), pedagogical content knowledge (PCK, pedagogical practices, and learning goals), and technological content knowledge (TCK, knowledge of technologies and teaching materials).

TPACK is a complex relationship of all the knowledge (technology, pedagogy, and content) [7]. The rapid innovation of technology and the dynamic evolution of teaching and learning perspectives have significantly contributed to TPACK research. Many studies have applied TPACK as a framework [7]–[9]. However, systematic reviews on TPACK, related to technology integration in education are still few, helpful to understand how correlated features are linked to the TPACK and technology integration issue. Therefore, this study was conducted. This systematic literature review study tries to conclude TPACK-related studies from 2010 to 2022. Three research questions were established for the current study: i) What were the instruments to assess the TPACK of preservice teachers from 2010 to 2022?; ii) What were TPACK domains' inter-correlations of preservice teachers from 2010 to 2022?; iii) What were TPACK's relationships with technology integration of pre-service teachers from 2010 to 2022?

2. RESEARCH METHOD

The research used preferred reporting items for systematic reviews and meta-analyses (PRISMA) for this systematic literature review (SLR) because it provides a standardized model for reporting and conducting SLR, a guideline developed to help ensure that this study is transparent, replicable, and comprehensive. This PRISMA takes an in-depth look at the studies on TPACK and technology integration for preservice teachers. This research examines how TPACK evolved within the time frame that has affected preservice teacher education programs. The impacts should be investigated to improve didactical decisions in the future and bridge the gaps to more adaptable but effective teaching. PRISMA is a procedure that has some steps, namely, search, screening, initial inclusion, eligibility, and inclusion [8], [9]. The main database for the search procedure is Science Direct for peer-reviewed articles. We selected the peer-reviewed since it is an important process for academic journals, a quality control mechanism that helps to ensure that the articles published in a journal are accurate, reliable, and of good quality. The time range for the search was from 2010 to March 2022.

2.1. Search

Initially, we identified a set of keywords, namely "TPACK", "TPCK", and "TPACK for technology integration," for our search. However, we revised our search strategy due to the excessively large number of results yielded by the aforementioned keywords. To illustrate, the Science Direct database returned over 5000 results when the term "TPACK" was searched. Similarly, a search for "TPCK" generated 1616 results. Besides, most of the journals are within the area of Medicine, namely Biochemistry, Molecular Biology, Cell Biology, Pharmacology Pharmacy, and Bio-Physics. Therefore, due to one of the study characteristics, which the participants are preservice teachers, the researcher changed the keywords into TPACK, preservice teacher; TPCK, preservice teacher; and TPACK, preservice teacher technology integration. As a result, 402 titles were obtained: 170 titles for "TPACK, preservice teacher, 75 titles for TPCK, preservice teacher, and 157 for "TPACK, preservice teacher and technology integration". The complete search elaboration is shown in Table 1.

Table 1. Search results

Keywords (n)	Year (n)	Article type (n)
"TPACK, preservice teacher" (170)	2022 (13); 2021 (39); 2020 (21); 2019 (16); 2018 (10); 2017 (9); 2016 (11); 2015 (15); 2014 (11); 2013 (8); 2012 (12); 2011 (2); 2010 (3)	Research articles (158); Review articles (7); Book chapters (1); Editorial (1); Short communication (1); Data article (1); Other (1)
"TPCK, preservice teacher" (75)	2022 (2); 2021 (9); 2020 (5); 2019 (3); 2018 (5); 2017 (4); 2016 (3); 2015 (11); 2014 (8); 2013 (5); 2012 (9); 2011 (7); 2010 (4)	Research articles (70); Review articles (1); Book chapters (1); Editorial (1); Short communication (1); Data article (1); Other (1)
"TPACK, preservice teacher, technology integration" (157)	2022 (11); 2021 (37); 2020 (20); 2019 (16); 2018 (9); 2017 (8); 2016 (9); 2015 (14); 2014 (9); 2013 (8); 2012 (11); 2011 (2); 2010 (3)	Research articles (82); Review articles (3); Book chapters (1); Editorial (0); Short communication (1); Data article (1); Other (1)

2.2. Screening

The titles (n=402) were screened for duplication. We used Microsoft Word's "Navigation" by copying and pasting one title into "Find" to search the duplicated titles by eliminating the duplicated titles one by one. Finally, 198 original titles were gained. Meanwhile, 204 entries were eliminated since they were only the repetition of the entries. The details are shown in Figure 1.

2.3. Initial inclusion

The initial inclusion for all titles was conducted with some criteria; Addressing instruments to assess TPACK, TPACK domains' inter-correlation and TPACK relationships with technology integration, Findings in English, empirical research, and being published from 2010 to March 2022. In this initial inclusion process, abstracts were read and discussed. The process successfully included 61 abstracts, while 137 abstracts were excluded since they did not meet one or more criteria for this initial conclusion. The criteria are informed in Figure 1.

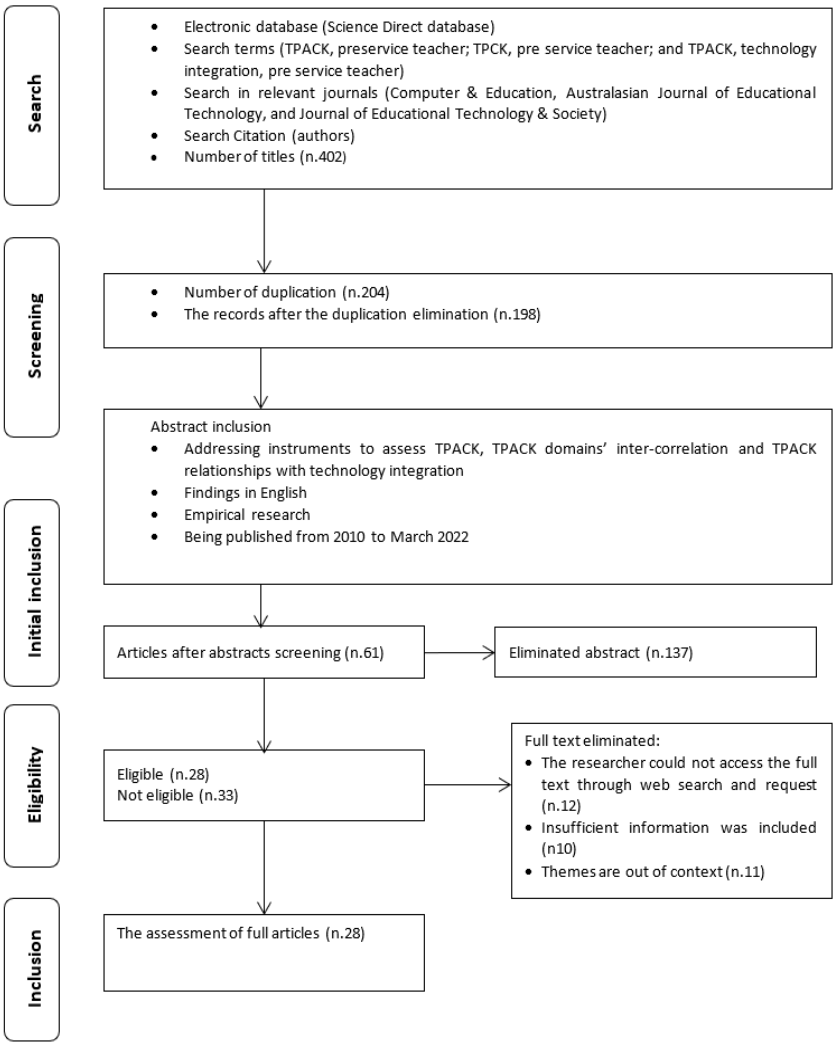

Figure 1. Flow of the diagram based on TPACK

2.4. Eligibility and inclusion

The 61 abstracts that have been included in the initial inclusion were searched for the full papers. However, 12 papers could not be fully accessed or were inaccessible. There were 10 of them had no sufficient information regarding TPACK, while 11 articles' themes were out of context, not representing preservice teachers' TPACK.

3. RESULTS AND DISCUSSION

3.1. Instrument to assess TPACK

Many instruments have been designed that involve TPACK as the framework. Schmidt *et al.* [10] produced the first and perhaps most well-known instrument in which they invited American preservice teachers as respondents to the study. The validity of the instrument was computed using Cronbach's alpha and construct

validity from data from 124 preservice teachers. Seven domains (TK, PK, CK, PCK, TCK, TPK, and TPACK) were produced from the instrumentation with 47 items [10]. Since then, many researchers have adapted the instrument but have failed to discover all seven domains [11]–[16]. For example, Koh *et al*. [13] could not validate the instrument for the Singaporean context through exploratory factor analysis (EFA). Involving 1,185 respondents, they only reported five distinctive domains, namely TK, CK, knowledge of pedagogy (KP), knowledge of teaching with technology (KTT), and knowledge from critical reflection (KCR). Further, research by Chai *et al*. [12], examining 214 preservice teachers' perspectives from Singapore, informed eight domains consisting of TK, CK subject teaching 1 (CKCS1), CK subject teaching 2 (CKCS2), PK, TPK, TCK, PCK, and TPACK.

Shinas *et al*. [15] did a construct validity of the Schmidt *et al*. [10] seven domains of TPACK through the EFA; the respondents were 365 preservice teachers. This experimental study was conducted after six months to contextualize TPACK-related course content. Eight domains were reported as: TK, PK, mathematical content knowledge (CKM), science content knowledge (CLS), literacy content knowledge (CKL), social science content knowledge (CKSS), TPK, and TPACK. Valtonen *et al*. [4] emphasized the skill of 21st-century teaching in relation to TPACK. Preservice teachers in their study should apply technology-based supporting activities during their teaching. They outlined the development and validation process of TPACK for the skills of 21st-century education. A newly developed self-assessment instrument was distributed to 94 preservice teachers in the 1st phase of their study, while it was addressed to 267 preservice teachers in the 2nd study. The results were obtained through EFA using oblique rotation that produced 36 valid and reliable items with seven domains; PK21st, CK old, CK 21st, TK, PCK 21st, TPK21st, and TCK21st.

Luik *et al*. [3] published an article about TPACK survey establishments in Estonia involving 413 preservice teachers at the University of Tartu. They reported three domains from the instrumentation (technological, pedagogical, and content). In recent years, Schmid *et al*. [17] examined their TPACK-based instrument through confirmatory factor analysis (CFA) involving 117 preservice upper secondary school teachers; 28 out of 42 items were validated. There were seven domains (TK, PK, CK, PCK, TCK, TPK, TPCK) had resulted from the study, similar to the first instrument [9]. The complete lists of the studies on the TPACK's instrument establishment and adaptation are exhibited in Table 2. This information would make a significant contribution to researchers who are interested in conducting research on the adaptation and establishment of items related to TPACK.

Table 2 Studies of instruments to assess TPACK

Study	n samples	Method	n items	n domains	Names of domains
[2]	17 preservice teachers	Cronbach alpha and qualitative	42 of 42 items	7	TK, PK, CK, PCK, TCK, TPK, TPACK
[3]	413 Estonian preservice teachers	Factorial analysis EFA, CFA	51 of 103 items	3	Technology, pedagogy, content
[4]	94 preservice teachers in study 1; 267 preservice teachers in study 2	EFA, oblique rotation	36 of 86 items	7	PK21st, CK old, CK 21st, TK, PCK 21st, TPK21st, TCK21st
[10]	124 preservice teachers in the United States	Construct validity	47 of 75 items	7	TK, PK, CK, PCK, TCK, TPK, TPACK
[11]	174 and 204	EFA	39 of 50 items	7	TK, PK, CK, PCK, TCK, TPK, TPACK
[12]	214 preservice teachers from Singapore	Factor analysis, EFA, and CFA	34 of 36 items	8	TK, CKCS1, CKCS2, PK, TPK, TCK, PCK, TPACK
[13]	1885 Singaporean preservice teachers	EFA	28 of 29 items	5	TK, CK, KP, KTT, KCR
[14]	229 Preservice teachers in study 1; 2017 preservice teachers in study 2	Factor analysis EFA and CFA	42 of 48	8	PCK, PK, TPACK, CK, TK, TPK, TCK, TKW
[15]	365 preservice teachers in the USA	Factor analysis, EFA and CFA	46 of 47 items	8	TK, PK, CKM, CLS, CKL, CKSS, TPK, TPACK
[16]	138 preservice mathematics teachers	Experimental study with reliability test and CFA	21 items	7	TK, PK, CK, PCK, TCK, TPK, TPACK
[17]	117 preservice upper secondary school teachers	CFA	28 out of 42 items	7	TK, PK, CK, PCK, TCK, TPK, TPCK

3.2. TPACK domains' inter-correlations

Besides reviewing the instruments to assess TPACK, we also gathered information on the inter-correlations among TPACK domains. The information provided in this study is expected to have significant implications for both researchers and practitioners. Specifically, it is anticipated that the findings of this research will aid in the development of more effective policies and strategies for integrating technology in

educational settings. Furthermore, it is expected to provide valuable insights for researchers who are interested in further exploring the relationship between TPACK factors and technology use [18]. Ultimately, the dissemination and application of the results of this study are likely to facilitate the advancement of the field of technology integration in education.

As shown in Table 3, there were nine studies between 2010 and 2022 detected in the systematic literature review, examining the TPACK domains' relationships. Chai *et al*. [19] assessed outputs from a course implementation and design of information and communication technology (ICT) on the core framework of meaningful learning and cyber wellness issues. The study investigated the correlations of TPACK domains among Singaporean preservice teachers. Prior to the implementation of the course, two questionnaires were administered to a sample of 668 preservice teachers. Following the course implementation, the questionnaires were again administered to 628 preservice teachers. The questionnaires encompassed seven TPACK domains, namely CK, PK, TK (Web 2.0 related), TCK, PCK, TPK, and TPACK. The data collected were analyzed using path analysis, which revealed several significant correlations among the domains. Specifically, statistically significant correlations emerged between PK and TPACK, PK and TPK, CK and TPK, and TK (Web 2.0 related) and TPK. However, other correlations, such as those between TPK, PCK, and TCK and TPACK, were found to be statistically insignificant.

Dong *et al*. [20] surveyed 390 preservice teachers and 394 in-service teachers regarding the seven domains of TPACK and two external variables, control beliefs (CB) and design disposition (DD). They reported the correlations among all domains through EFA, CFA, and covariance-based structural equation modeling (CB-SEM). Especially for inter-correlations among TPACK domains, most hypotheses were supported, namely between CK and TCK, CK and TPACK, TK and TCK, PK and PCK, PK and TPK, and TPK and TPACK. Meanwhile, four TPACK domains' correlations were considered insignificant; PCK to TPACK, CK to PCK, TK to TPACK, and PK to TPACK [20].

Koh and Sing [21] investigated seven constructs of TPACK describing preservice teachers' technology use in education. The study elaborated on Singaporean preservice teachers' TPACK perceptions and applied a stepwise regression model. The study assessed the relative impact of two demographic information categories: age and gender. The study's findings reported that TPACK constructs substantially affected preservice teachers' TPACK perceptions, whereas the demographic information was not significant. For the TPACK domains' inter-correlations, an insignificant relationship was found between TK and PCK, while the other associations were significant at $p<.005$ or $p<.001$.

Pamuk *et al*. [22] explored the TPACK's domain correlations among Turkish preservice teachers. Through preservice teachers' shared experiences, an instrument was developed and examined for its reliability and validity to achieve the purposes of the study. In the first phase, the study involved 177 preservice teachers, and 882 preservice teachers from the same country in the second phase. They used a path analysis through SEM to answer the research question about the inter-correlations among TPACK domains. They informed the TPACK correlational significances, leading to a valid and reliable model. The significant inter-correlations existed between TK and TPK, TK and TCK, PK and TPK, PK and PCK, CK and PCK, CK and TCK, TCK and TPACK, TPK and TPACK, and between PCK and TPACK. Three correlations were not significant; between CK and TPACK, PK and TPACK, and TK and TPACK.

Another study by Scherer *et al*. [23] used T domains consisting of TK, TPK, TCK, and TPCK to assess preservice teachers' self-efficacy linked with the 'T-domains.' In the validity establishment, they examined the factor structure of the domains. They discussed the results of the study in terms of gender and educational tracks. The data to assess the inter-correlations of TPACK domains were obtained from 665 preservice teachers from 18 educational training institutions for teachers in Belgium. The data were analyzed using factor correlation that results in six correlational relationships: between TPK and TCK, TPK and TPCK, TCK and TPCK, TK and TPK, TK and TCK, and TK and TPCK.

Valtonen *et al*. [24] informed a new TPACK questionnaire that was based on 21st-century skills. In correlating all TPACK domains, Valtonen *et al*. [24] used Pearson product-moment correlations. The data were from 276 Finnish preservice teachers from Finland. The findings indicate that all TPACK domains were mutually related [24]. Schmid *et al*. [17] also aimed to measure the inter-correlations among TPACK domains in a study conducted in Switzerland. There were 10 relationships (e.g., CK->TCK and CK->PCK) significantly correlated, while four correlations were not supported. Using Pearson product-moment correlations (r), Baier and Kunter [18] examined the intercorrelations between TPK, PK, and TK. The study found positive and significant relationships between TPK and PK, PK and TPK, and PK and TK.

Table 3. TPACK domains' inter-correlations

Study	n. sample	Method	TPACK variables	Inter-correlation
[17]	117 preservice upper secondary school teachers	Confirmatory factor analysis	TK, PK, CK, PCK, TCK, TPK, TPCK	CK->TCK (β=.34)** CK->PCK (β=.23)** TK->PCK (β=.65)** TK->TPK (β=.44)** TK->TCK (β=.46)** PK->PCK (β=.73)** PK->TPK (β=.66)** CK->TCK (β=.61)** TPK->TPCK (β=.86)** TPK->TPCK (β=.41)**
[18]	245 preservice teachers	Pearson product-moment correlations (r)	TPK, TK, PK	TK->TPK (r=.36)** PK->TPK (r=.51)** TK->PK (r=.18)**
[19]	668 (before the course); 607 preservice teachers (after the course)	Path analysis (SEM)	CK, PK, TK (Web 2.0 related), TCK, PCK, TPK	PK->TPACK (β=.61)** PK->TPK (β=.52)** CK->TPACK (β=.19) PK->TPK (β=.52)** TK (Web 2.0 related)->TPK (β=.14)**
[20]	390 preservice teachers; 394 in-service teachers	Covariance-based structural equation modeling	TK, CK, PK, TPK, TCK, PCK, TPACK	CK->TCK (β=.13)** CK->TPACK (β=.10)* TK->TCK (β=.63)** TK->TPK (β=.46)** PK->PCK (β=.64)** PK->TPK (β=.35)** TPK->TPACK (β=.31)**
[21]	350 Singaporean preservice teachers	Stepwise regression model	TK, CK2, CK2 PK, TPK, TCK, PCK, TPACK	CK1->PK(.54)** TPK->TCK(.53)** TPK->TPACK(.68)**
[22]	177 Turkish preservice teachers (1st phase); 882 Turkish preservice teachers (2nd phase)	Path analysis (CB-SEM)	TK, CK, PK, TPK, TCK, PCK, TPACK	TK->TPK (β=.74)** TK->TCK (β=.62)** PK->TPK (β=.28)** PK->PCK (β=.70)** CK->PCK (β=.34)** CK->TCK (β=.19)** TCK->TPACK (β=.58)** TPK->TPACK (β=.41)** PCK->TPACK (β=.16)**
[23]	665 preservice teachers in 18 Belgium training institutions	Factor correlation	TK, TPK, TCK, TPCK	TPK->TCK (.98)** TPK->TPACK (.99)** TCK->TPACK (.98)** TK->TPK (.86)** TK->TPK (.81)** TK->TPCK (.81)**
[24]	276 preservice teachers from Finland	Pearson product-moment correlations (r)	PK21, TK, CK, PCK21, TCK	PK21->PCK21 (r=.74)** CK->PCK 21 (r=.47)** CK->TK (r=.25)** PCK21->TK (r=.21)** TCK->PK21 (r=.62)** TK->PK21 (r=.22)** TPK21->PK21 (r=.51) TCK->TK (r=44)** TPK21->TCK (r=.72)** TPK21->PCK21 (r= 62)** TCK->PCK21 (r=.62)**
[25]	293 preservice teachers	Pearson product-moment correlations (r)	TK, CK, PK, TPK, TCK, PCK, TPACK	CK->TCK (β=.41)** CK->PCK (β=.61)** TK->PCK (β=.65)** TK->TPK (β=.70)** PK->PCK (β=.60)** PK->TPK (β=.38)** CK->TCK (β=.61) TPK->TPACK (β=.63)** TCK->TPACK (β=.47)** PCK->TPACK (β=.58)**

Note. *p<.05; **p<.01

3.3. TPACK's relationships with technology integration

Many studies have revealed the relationship between TPACK domains and technology integration, such as between PK and integration of ICT [26], [27], TPK and technology integration [28], TPACK and intention to use technology [29], PK and lesson plan for technology use [30], TPACK and behavioral intention

to adopt technology into teaching [31], [32], TPACK and technology integration [23], and digital nativity and TPACK [33]. Aslan and Zhu [27] conducted a study to investigate the extent to which ICT-related variables, and one of them was PK. They combined some indicators, and one of them was PK. There were 599 Turkish preservice teachers involved as their study sample. The instrument validation and reliability assessment process involved content validity and factor analysis through EFA and CFA. Using CB-SEM as the primary data analysis tool, they reported that PK significantly predicted ICT integration into teaching (β=.330). The PK predicted and accounted for 17% of the ICT integration into teaching practices.

Joo *et al*. [29] studied the correlation between some predictors, including TPACK, technology acceptance model (TAM), and teachers' self-efficacy to intention to use technology. There were 296 respondents from three Korean universities completed the established instruments. Path analysis through CB-SEM was utilized to analyze the data. From the study's findings, TPACK was insignificant in predicting teachers' intention to adopt technology; however, it was reported to be a significant predictor when it indirectly indicated the intention to use ICT through perceived usefulness (PU) [29]. They also discussed the recommendations and suggestions for all stakeholders in the study area.

Krauskopf *et al*. [30] elaborated on the integration of the mental model within the theory of TPCK. They informed on research on the investigation of PK that the survey instrument was addressed to preservice German teachers as the predictor of mental models of YouTube and how these affect lesson plans for technology integration in teaching. They perceived the active mental models of YouTube and presented a quantitative data approach recommending mental models as mediators to affect PK on participants' lesson plans. The study findings informed that PK was a predictor affecting the ideal use of YouTube (β=.33) and YouTube's intended use (β=.40).

Teo *et al*. [31] investigated preservice teachers' intentions to use computers in traditional and innovative teaching of mathematics in primary schools. They extended TAM and TPACK by extracting other variables. There were 226 respondents from Serbia invited to complete a 22-item questionnaire in 20 minutes. The data was analyzed using SEM. The TPCK was the predictor for behavioral intention, the traditional use of technology, and innovative technology use. Both correlations were significant in that TPCK is stronger in predicting behavioral intention and innovative use of technology (β=.33) than behavioral intention and traditional use of technology (β=.30). The implications for mathematics teaching were elaborated on and discussed [31].

In another study, Teo *et al*. [32] facilitated an optional perspective for technology integration research by assessing and investigating predictors of preservice teachers in integrating Web 2.0 technologies for instructional activities. The study proposed eight hypotheses, one of the predictors being TPACK. The data was gathered from 464 preservice teachers from two universities in China. Using CB-SEM, they elaborated on all predictors' influences on the intention to use the technology. The finding informs that TPACK was significant in predicting intention to use technology. The results can help Chinese stakeholders better understand the realities of Web 2.0 integration in education.

Yurdakul [33] built an SEM model that predicts the correlation between TPACK competencies and digital nativity from Turkish preservice teachers (n=1493). Two instruments were utilized: a TPACK-deep scale and a Turkish adaptation of the digital native assessment scale (DNAS). The SEM examined the hypotheses that elaborate digital nativity as the TPACK competency predictor. The finding reported that the preservice teachers perceived themselves to have a high-level ability in digital nativity and TPACK competency. The main conclusion informed that digital nativity significantly affects TPACK competency. Suggestions and recommendations for practice and future studies research were also provided.

Santos and Castro [26] conducted a study on 67 preservice teachers to understand the application of TPACK on EdTEch Tools. Data were analyzed with SPSS using Pearson product-moment correlations (*r*). Two constructs were involved in TPACK and technology integration, TPACK and EdTEch tools. They revealed the significant relationships between TPACK and EdTEch Tools with an *r*-value of 302. Given that one of the aims of the present study is to investigate the existing literature on the association between TPACK factors and technology use intention or behavior, we have provided a comprehensive overview of the relevant information [34]–[36]. This detailed exposition is intended to assist researchers in conducting informed discussions on this relationship as seen in Table 4.

By providing a comprehensive overview of the existing literature, the research is laying the foundation by identifying what is already known about the topic [37]–[39]. This allows us to identify gaps in the existing knowledge and to develop research questions or hypotheses that can help to further our understanding of the relationship between TPACK factors and technology use [40], [41]. Additionally, the comprehensive overview of the relevant information can serve as a valuable resource for other researchers interested in this topic. Moreover, the comprehensive overview of existing literature can help contextualize findings and evaluate the significance of the research [42]–[45]. By identifying what is already known about the topic, can situate the research within a larger body of work and demonstrate how the findings contribute to this broader conversation.

This can help to establish the importance of the research and demonstrate its relevance to other scholars and practitioners.

Furthermore, by identifying gaps in the existing knowledge, this study can contribute to developing new theories or frameworks that can help explain the relationship between TPACK factors and technology use [46], [47]. This can help to advance the field of educational technology and provide insights that can be used to improve technology integration in educational settings [48], [49]. Lastly, the comprehensive overview of the relevant information can serve as a valuable resource for other researchers who are interested in this topic [13], [14]. It can help to guide future research, provide a starting point for literature reviews, and offer insights into the methodologies and approaches that have been used in previous studies [50]. By sharing the findings with the wider academic community, it can contribute to the advancement of knowledge and promote a more collaborative and informed approach to research in the field of educational technology.

Table 4. Correlation between TPACK and intention to use or actual integration of technology

Study	Sample	Method	Predictors	Dependent variable	Correlation
[23]	688 preservice teachers	SEM	TK, TPACK	Technology integration	TPACK and technology integration (r=.12)**
[26]	67 preservice teachers	Pearson product-moment correlations (r)	TPACK	EdTEch tools	TPACK and EdTEch tools (r=.302)**
[27]	599 Turkish preservice teachers from 6 universities	CB-SEM	PK	Integration of ICT	PK->Integration of ICT* (β=.330)**
[28]	320 respondents	Path analysis (CB-SEM)	Technology integration (ICT tools and social media)	TPCK	Technology integration (ICT tools) ->TPACK (β=.79)** Technology integration (Social media)->TPACK
[29]	296 Korean preservice teachers	Path analysis (CB-SEM)	TPACK	Intention to use ICT	TPACK->intention to use ICT
[30]	60 preservice German teachers	Mediation analysis	PK	Ideal use of YouTube Intended use of YouTube	PK->Ideal use of YouTube (β=.330)** PK->Intended use of YouTube (β=.40)**
[31]	226 Serbian preservice teachers	Path analysis (CB-SEM)	TPCK	Behavioral intention, traditional use of technology Behavioral intention, innovative use of technology	TPCK->Behavioral intention, traditional use of technology (β=.30)** TPCK->Behavioral intention, innovative use of technology (β=.33)**
[32]	464 Chinese preservice teachers	Path analysis (CB-SEM)	TPACK	Intention to use	TPACK->Intention to use (β=.260)**
[33]	1439 Turkish preservice teachers	Path analysis (CB-SEM)	Digital Nativity	TPACK	Digital nativity->TPACK (β=.59)**

4. CONCLUSION

This systematic review aims to provide future researchers with a comprehensive view and analysis of earlier literature regarding TPACK and technology integration in education. The goal is to generate and share the results of the prior studies by identifying research methodologies (e.g., self-report measures, open-ended questionnaires, performance assessments, interviews, and observations) to explore preservice teachers' TPACK. It also looks at the relationships between TPACK and technology integration studies. This PRISMA research would significantly assist teacher educators and education programs in understanding preservice teachers' TPACK development and technology integration in education to issue appropriate policies and researchers to adapt the discussed articles for future studies. In brief, 11 studies can be references for the instruments to assess TPACK perceived by preservice teachers. There were nine works informed TPACK domains' inter-correlations of preservice teachers from 2010 to 2022. Besides, TPACK's relationships with technology integration of pre-service teachers were reported in nine studies. Teacher educators and other related parties, such as tutors and school principals, substantially impact preservice teachers' professional development. Therefore, modeling the use of technology in courses and K–12 classroom settings is particularly important for TPACK development. Preservice teachers should access high-quality technological activities during their teacher training program. Preservice teachers' K–12 field experiences must also be included in the

technology integration and modeling initiatives; as a result, field experiences might influence how preservice teachers use and incorporate technology in their future classrooms.

The researchers considered some limitations of the current study, e.g., the sample is only limited to preservice teachers and the method should be more developed. However, this PRISMA work can guide future studies in TPACK by expanding on what researchers have already accomplished. Qualitative and quantitative inquiries should be extended based on this research, particularly for preservice teachers in developing countries. We also recommend systematic literature reviews for in-service teachers for future research to improve how teachers are equipped and use technology in teaching and learning activities.

ACKNOWLEDGEMENTS

This research is fully funded by Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi, Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia; Grant number (214/E5/PG.02.00/PT/2022).

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